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BEFORE THE
UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY

IN RE APPLICATION FOR A FUEL ADDITIVE WAIVER FILED BY ETHYL CORPORATION UNDER § 211(f)(4) OF THE CLEAN AIR ACT

APPENDICES TO THE WAIVER APPLICATION
FOR THE HiTEC 3000 PERFORMANCE ADDITIVE

VOLUME THREE

APPENDICES 6, 7, 8, 9, 10 AND 11

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HiTEC 3000 WAIVER APPLICATION APPENDICES

Appendix No.

VOLUME ONE

1. Fleet Test Protocol

2. Statistical Analyses of the HiTEC 3000 Additive Test Program Data

   2A - Statistical Analysis of Automotive Exhaust Emissions in Support of Ethyl's HiTEC 3000 Fuel Waiver Application (Systems Applications, Inc. May 4, 1990).

   2B - Analysis of Ethyl Emission Test Data (Roberson Pitts, Inc. April 1990)

   2C - Instantaneous Effects Analysis

VOLUME TWO

3. Durability Testing, Materials Compatibility Testing, Evaporative Emissions, Driveability, and Particulate Emissions

4. Effects of the HiTEC 3000 Performance Additive on Hydrocarbon Species in Automobile Exhaust Emissions

5. Use of the Urban Airshed Model to Assess the Effects of HiTEC 3000 Performance Additive on Urban Air Quality (Systems Applications, Inc. May 4, 1990)

VOLUME THREE

6. Additional Environmental, Economic and Energy Benefits Associated with Use of the HiTEC 3000 Additive

7. Total Pollutant Reductions

8. Health and Environmental Implications of Use of HiTEC 3000 as a Fuel Additive

9. Compilation of Scientific Studies that Provide Additional Support for the HiTEC 3000 Additive Waiver Application

(Volume Three cont'd)

10. The Slight Increase in Hydrocarbon Emissions in Test Vehicles Using the HiTEC 3000 Additive is Not Material To This Waiver Application

11. The Impact of the HiTEC 3000 Performance Additive On Compliance with Future Emission Standards

Appendix 6

APPENDIX 6

ADDITIONAL ENVIRONMENTAL, ECONOMIC, AND ENERGY BENEFITS ASSOCIATED WITH USE OF THE HiTEC 3000 ADDITIVE

A major benefit associated with use of the HiTEC 3000® Performance Additive ("the HiTEC 3000 additive") is that it reduces total automobile exhaust emissions of both criteria and other pollutants.[1/] This is not, however, the only benefit associated with the use of the HiTEC 3000 additive. This Appendix describes the other environmental, economic, and energy benefits associated with use of the HiTEC 3000 additive in unleaded gasoline. Among these additional benefits are a reduction in the pollutants emitted by refineries, a reduction in the aromatics content of gasoline, the potential to reduce gasoline vapor pressure, a substantial reduction in crude oil requirements, possible reductions in capital investments in the refinery industry, and a substantial reduction in the cost of achieving necessary octane levels in unleaded gasoline.

Many of these benefits are discussed in a report independently prepared by Turner, Mason and Company ("Turner Mason"). The Turner Mason report is attached to this Appendix as Attachment 6-1. Ethyl Corporation contracted with Turner Mason to determine how use of the HiTEC 3000 additive might affect the oil refining industry. Ethyl Corporation chose Turner Mason to conduct the study because of Turner Mason's reputation as a reliable, unbiased consulting firm, which they developed from

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1/ *See* Appendices 2A, 2B and 4.

years of experience working with the American Petroleum Institute, the National Petroleum Council, and individual oil companies. While the Turner Mason report speaks for itself, highlights from the Turner Mason study, as well as other benefits associated with use of the HiTEC 3000 additive, are discussed below.

I. USE OF THE HiTEC 3000 ADDITIVE WILL REDUCE REFINERY EMISSIONS.

Turner Mason concludes that use of the HiTEC 3000 additive in unleaded gasoline has the potential to reduce total refinery emissions by a little over 2 percent.[2/] Nitrogen oxide emissions could be reduced by as much as 11 million pounds per year (ppy), carbon monoxide emissions could be reduced by 3 million ppy, particulate emissions could be reduced by 1.1 million ppy, sulfur oxide emissions could be reduced by 150,000 ppy, and carbon dioxide emissions could be reduced by almost 10 billion ppy.[3/] These reductions in refinery emissions are the result of the octane boosting effect of the HiTEC 3000 additive. Refiners could take advantage of this boost in octane by lowering the octane-severity of process units which would reduce process unit furnance loads.[4/]

[2/] Attachment 6-1, at p. 20.

[3/] Id., at p. 1.

[4/] Id., at p. 20, and Table 18.

II. USE OF THE HiTEC 3000 ADDITIVE WILL REDUCE THE AROMATICS CONTENT OF UNLEADED GASOLINE.

The Turner Mason report also concludes that the aromatics in gasoline could be reduced by about 1.2 percentage points (from 31.2% to 30%) if refineries blend the HiTEC 3000 additive into all unleaded gasoline.[5] This represents a reduction in total gasoline aromatics of almost four percent. In particular, use of the HiTEC 3000 additive in unleaded gasoline could lower the benzene content of gasoline by 0.1 percentage points (from 1.7% to 1.6%), or almost a six percent reduction in benzene content.[6] It should be noted that these values for aromatic and benzene reductions are minimum reductions because the linear programming model used by Turner Mason was not instructed to produce gasoline with decreased aromatic content. Other analysts have independently estimated that use of the HiTEC 3000 additive at 0.03125 g Mn/gal would entail a reduction in the aromatic content of unleaded gasoline of at least two percentage points.[7]

The reduction in aromatics occurs because use of the HiTEC 3000 additive, as an octane booster, lowers refinery reforming requirements. Reforming is the principal process for octane improvement which achieves octane enhancement by increasing the

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[5] Id., at p. 22, and Table 24.

[6] Id.

[7] See, e.g., Unzelman, G.H., Maintaining Product Quality in a Regulatory Environment, 1990 National Petroleum Association Annual Meeting, March 25-27, 1990, attached in Appendix 9, at Attachment 9-4, p. 13.

aromatic content of gasoline. Use of the HiTEC 3000 additive to increase octane allows less reforming and thus lowers aromatic content.[8/]

A reduction in gasoline aromatics of this sort would be particularly topical because recent announcements by the oil and automotive industries have pointed out the need to improve the quality of gasoline to meet suggested revisions in the Clean Air Act. A multi-million dollar joint study by the two industries is now underway. The purpose of the study is to investigate changes to both fuel and engine/exhaust conversion systems that further reduce the quantity, toxicity and reactivity of total vehicle emissions. One change in this "reformulated gasoline" will be to reduce total aromatics and specifically benzene. This is precisely the effect to be expected from use of the HiTEC 3000 additive in unleaded gasoline.

III. USE OF THE HiTEC 3000 ADDITIVE HAS THE POTENTIAL TO REDUCE THE VAPOR PRESSURE OF GASOLINE.

When refining gasoline from crude oil, highly volatile materials such as butanes are produced. Although butane has a high octane quality, it raises the vapor pressure of gasoline. Gasoline with a high vapor pressure can contribute to increased evaporative and running losses from vehicles in hot weather.[9/]

[8/] Attachment 6-1, at p. 22; Appendix 9, at Attachment 9-4, p. 9.

[9/] The maximum vapor pressure of summer grade gasoline has recently been reduced for this very reason. See 54 Fed. Reg. 11868 (1989).

Because the HiTEC 3000 additive at a concentration of 0.03125 grams manganese per gallon raises the quality of unleaded gasoline about one octane number, the operating severity for refinery process units can be reduced. This reduces butane production, making it less difficult to meet the new, lower vapor pressure specifications for gasoline.

IV. USE OF THE HiTEC 3000 ADDITIVE WILL SUBSTANTIALLY DECREASE CRUDE OIL REQUIREMENTS.

Another benefit associated with use of the HiTEC 3000 additive is a substantial reduction in crude oil requirements to produce gasoline. Because use of the HiTEC 3000 additive reduces refinery process unit severity, gasoline yields improve thereby reducing the need for crude oil stocks.[10/] Turner Mason projects that use of the HiTEC 3000 additive in unleaded gasoline will reduce crude oil requirements by about 82,000 barrels of crude oil per day, or over 30 million barrels of oil per year.[11/] At $18/barrel, this crude oil savings amounts to a possible reduction in the balance of payments for the United States of $540 million per year.

10/ Attachment 6-1, at p. 20, and Table 17. A 1986 Canadian study supports this conclusion. The study, entitled "Optimized Linear Programming Analysis of the Effect of Oxygenated Fuels on Canadian Oil Refineries" (Energy, Mines and Resources, Canada), indicates that the use of the HiTEC 3000 additive at the maximum allowable level of 18mg/L (0.068 grams per U.S. gallon) in Canada allowed reformers to operate at three Research Octane Numbers lower severity than if the HiTEC 3000 additive had not been used.

11/ Attachment 6-1, at p. 20.

With U.S. domestic crude oil production decreasing each year, petroleum imports will have to increase to make up the difference. This will adversely affect our national security. In 1989, for example, imported crude oil and petroleum products will supply over 40% of the total U.S. demand. This figure is expected to jump substantially (to over 50%) in the next few years.

Under these circumstances, the consequence of a disruption in the flow of oil imports to the United States could be disastrous. For this reason, the government several years ago began to stockpile crude oil supplies in the Strategic Petroleum Reserve (SPR). As of August 1, 1989, the SPR contained about 575 million barrels of crude oil, or about 79 days of net oil imports.[12/] The supply target for the SPR is a 90 day net supply. At the current fill rate, the SPR will not reach this targeted supply for some time. Moreover, the emergency supply problem is likely to worsen because Congress appropriated funds to purchase only 50,000 barrels per day in fiscal 1990.

[12/] See Memorandum dated October 17, 1989 from the Petroleum Industry Research Foundation, Inc. to the Department of Energy in response to the DOE's Notice of Inquiry on "Alternative Financing Methods for Funding the Purchase of Strategic Petroleum Reserve Supplies and Facilities," attached hereto as Attachment 6-2.

Use of the HiTEC 3000 additive can help to alleviate these problems, and therefore enhance our national security, by significantly reducing the nation's crude oil requirements.[13/]

V. USE OF THE HiTEC 3000 ADDITIVE COULD ALLOW REFINERIES TO REDUCE INVESTMENT IN EXPENSIVE NEW PROCESS EQUIPMENT.

Turner Mason also estimated the decrease in refinery facility requirements if refiners can be assured of long-term acceptance of the use of the HiTEC 3000 additive in unleaded gasoline. A decrease in refinery facility requirements occurs because of the general reduction in octane processing requirements associated with use of the HiTEC 3000 additive.[14/] Turner Mason projects that conventional low pressure reformer unit investments, and the investments associated with MTBE production, will decrease with use of the HiTEC 3000 additive. Together, these changes decrease capital investment needs in the refinery industry by about $730 million. Moreover, a reduced need for new refinery equipment would lower fugitive emissions of volatile organic compounds by 1300 tpy.[15/]

13/ Indeed, when oil supplies were limited in 1979, EPA suspended the restriction on use of the HiTEC 3000 additive in order to extend unleaded fuel stocks. See 44 Fed. Reg. 32281 (1979).

14/ Attachment 6-1, at p. 21.

15/ Id., at p. 21. Fugitive emissions are emissions from pump and compressor seals, valves, flanges and other refinery process unit equipment. Turner Mason estimates that the decrease in refinery emissions associated with reduced refinery investment is 1.6 percent, somewhat less than the 2.1 percent reduction associated with the "reduced severity" scenario for the refining industry. See id., at p. 20. Similarly, the reduction in crude

(continued...)

VI. <u>USE OF THE HITEC 3000 ADDITIVE WILL REDUCE THE COST OF ACHIEVING NECESSARY OCTANE LEVELS IN UNLEADED GASOLINE.</u>

The primary benefit associated with use of the HiTEC 3000 additive is that it enhances octane at a cost which is substantially less than that associated with alternative methods of enhancing octane. In this regard, Turner Mason concludes that the octane improvement costs associated with use of the HiTEC 3000 additive are approximately one-third those of competing methods of increasing octane.[16/] The cost of improving octane using the HiTEC 3000 additive is 8 to 12 cents per octane number barrel ("ONB"). Competing costs, by contrast, range anywhere between 30 to 60 cents per ONB.[17/]

In a competitive gasoline market, the cost savings associated with use of the HiTEC 3000 additive will, at least in part, be passed on to consumers in the form of lower prices at the gasoline pump. This, in turn, will allow consumers to invest more of their income in other productive endeavors, thereby benefitting the American economy.

<u>CONCLUSION</u>

Together, these environmental, energy, and economic benefits

[15/] (...continued)
oil requirements drops from 82,000 barrels a day to 4000 barrels a day under the reduced investment scenario. <u>Id.</u>, at Table 17. The smaller savings in crude oil under the reduced investment scenario occurs because with fewer new refinery units, the existing processing units must operate under somewhat more severe conditions. <u>See</u> <u>id.</u>, at p. 20.

[16/] <u>Id.</u> at p. 17, and Table 11.

[17/] <u>Id.</u>

associated with the use of the HiTEC 3000 additive provide additional justification for granting a waiver for use of the HiTEC 3000 additive in unleaded gasoline.

EXECUTIVE SUMMARY

A waiver from the Environmental Protection Agency (EPA) for the use of the performance additive HiTEC 3000 in unleaded gasoline in the 1990s will significantly reduce petroleum refinery emissions, conserve crude oil, cause beneficial changes in gasoline composition and decrease expensive process unit investments. By providing up to one octane number boost in unleaded gasoline, using HiTEC 3000 will allow reduced process unit furnace loads and emissions at constant finished gasoline octane numbers. Reformer severity reductions will lower benzene and other aromatics concentration in finished motor gasoline. An assured long-term availability of HiTEC 3000 would reduce the need for expensive process unit investments and subsequently reduce refinery fugitive emissions.

Using HiTEC 3000 will reduce petroleum refinery process furnace emissions. This performance additive boosts the octane number of unleaded gasoline by up to one octane number. Refiners could take advantage of this boost by lowering the octane-severity of process units which would reduce process unit furnace loads. Calculated total furnace emissions should be reduced at all U.S. refineries by about:

	tons per year
NO_x	5,500
CO	1,500
Particulates	550
SO_x	75
CO_2 (thousands)	4,800

ATTACHMENT 6-1

REDUCED REFINERY EMISSIONS

AND COSTS

VIA HiTEC 3000 IN UNLEADED GASOLINE

George W. Michalski
Robert E. Cunningham
John R. Auers

November 1989

TURNER, MASON & COMPANY
Consulting Engineers

These computed reductions represent about 2.1% of total refinery furnace emissions.

Using HiTEC 3000 in unleaded gasoline will conserve crude oil. Reducing process unit severity improves gasoline yield, which would result in savings of about 82,000 barrels of crude oil per calendar day (MBPCD) for all U.S. refineries.

Adding HiTEC 3000 will reduce the concentration of benzene and other aromatics in gasoline. Reforming, the principal process for octane improvement, achieves octane boost by increasing the aromatic content of gasoline. Use of HiTEC 3000 to increase octane will require less reforming and thus lower aromatic content, including benzene. Turner, Mason & Company (TM&C) estimates that aromatics content of gasoline will decrease by 1.2% from a projected level of 31%. TM&C calculated a reduction in benzene content from 1.7% to 1.6%.

Alternatively, EPA assurance of long-term permission for refiners to use HiTEC 3000 will allow refiners to reduce investments in expensive new process equipment. TM&C estimated the reduction in U.S. refinery investment at nearly $0.75 billion. Because of a lesser number of new process units, fugitive emissions would be reduced by about 1,300 tons per year. The reduced investment case also includes reductions in throughput and severity on process equipment. As a result, estimated U.S. refinery furnace emissions should decline as follows:

	tons per year
NO_x	4,200
CO	1,100
Particulates	440
SO_x	55
CO_2 (thousands)	3,500

Even if refiners emphasize investment savings, substantial decreases in refinery furnace emissions of about 1.6% will occur. Also, gasoline aromatic concentration will decrease by about 1% and benzene concentration by 0.1%.

EMISSIONS

Petroleum refineries operate under air permits which regulate their emission of the following four "criteria" pollutants:

- Nitrogen oxides – NO_x;
- Carbon monoxide – CO;
- Total suspended particulates – TSP; and
- Sulfur dioxide – SO_2.

These are called criteria pollutants because a National Ambient Air Quality Standard (NAAQS) has been set for each under the Clean Air Act. Carbon dioxide (CO_2) is not a criteria pollutant, but it has also been addressed in this report because of detrimental environmental, or "greenhouse", effects attributed to it.

A typical air permit sets limits on the total plant emissions of the criteria pollutants and also usually designates maximum allowable emissions levels for specific point sources. State reporting requirements can be on an annual, quarterly, or even monthly basis. In some cases, continuous emissions monitors (CEMs) are required on major emissions sources, and in those situations, the actual emissions can be measured quite accurately. In most cases, however, particularly with fired process heaters and steam boilers, CEMs do not exist, and emissions have to be calculated using various methods. These methods can all be translated to a relationship between mass of emissions released to unit of fuel fired (pounds/million BTU).

nitrogen oxides

Two nitrogen oxide compounds, nitrogen oxide (NO) and nitrogen dioxide (NO_2), are considered significant air pollutants and health hazards, even at low concentrations. They are involved in the formation of both smog and acid rain. The term NO_x is commonly used to refer to the sum of NO and NO_2, expressed as NO_2.

Petroleum refineries are a major source of NO_x emissions. They are formed during the high temperature combustion of fuel with air, which results in direct reaction of atmospheric nitrogen with atmospheric oxygen to form NO_x. NO is the primary oxide of nitrogen formed within the fired heaters. NO_2 is formed when the flue gases exit to the atmosphere, where the NO is further oxidized to NO_2 in the presence of an abundance of oxygen at lower temperatures.

Basic variables involved in the formation of NO_x during fuel combustion are temperature, residence time and percent of theoretical combustion air, with increases in each of the variables resulting in increased NO_x formation.

Various NO_x control techniques exist, such as two-stage combustion, off-stoichiometric firing, flue gas recirculation and modified burner configuration. All of these techniques are aimed at reducing one or more of the three basic kinetic variables. TM&C experience indicates that, with existing equipment, refinery fired heaters emit NO_x at an average overall rate of 0.15 pounds per million BTU. This is somewhat higher than the EPA limit of 0.12 pounds per million BTU for new fired heater installations. This current limit applies to furnaces which have been built since the early 1980s, and it replaced an earlier limit which was 0.2 pounds per million BTU. In the future, this regulation for new installations is expected to continue to decrease. The Los Angeles area already requires new installation NO_x emission rates below 0.06 pounds per million BTU. The EPA may lower their NO_x limit to 0.03 pounds per million BTU for new installations by 1992.

sulfur dioxide

SO_2 emissions have received particular attention recently in the media and the legislative arena, as they are probably a major cause of acid rain (along with NO_x). SO_2 emissions are caused by the reaction of sulfur in the fuel with oxygen made available during combustion. The level of SO_2 emission is directly related to the amount of sulfur in the fuel, independent of combustion conditions. The power-generating industry, which uses significant amounts of high sulfur coal as fuel, is the primary source of industrial SO_2 emissions in the U.S. By comparison, the petroleum refining industry, due to its reliance on low sulfur content gas plus some low sulfur liquid fuels, is a relatively small generator of SO_2 emissions in the U.S.

To determine an emission factor for SO_2 from refinery fired heaters, it is necessary to estimate the average sulfur content of the fuel used at refineries. Current EPA regulation limits the gaseous fuels to a sulfur content of 0.1 grain/SCF, which equals about 160 ppm. Our experience with refinery operations indicates that the current overall average is far below this limit, at an estimated 25 ppm. This translates to an emission factor of 0.002 pounds of SO_2 per million BTUs of gas fired.

Refinery liquid fuel is also low sulfur, but it is significantly higher in sulfur content than gas fuels, resulting in a much higher SO_2 emission factor than gas. Our estimate of the average sulfur content of fuel oil burned in refineries is 0.3 weight %, with a corresponding emission factor of 0.33 pounds of SO_2 per million BTU fired.

carbon monoxide

Automobiles are the major source of carbon monoxide (CO) pollution, a major component of smog, with the refineries again a relatively minor contributor. CO is formed from incomplete combustion of hydrocarbons and can be significantly reduced by modifying combustion conditions. From flue gas analysis data at various refineries, we estimate that the average refinery fired heater has a CO concentration of about 50 ppm in the fuel gas. This translates to an emission factor of 0.04 pounds of CO per million BTU of fuel fired.

particulates

Particulate emissions, which are also a contributor to smog, are primarily a function of the ash content of the fuel, with combustion conditions also playing a role. The power industry is the primary industrial generator of particulates due to its reliance on solid fuels. The refining industry is a much smaller contributor because of its use primarily of gaseous fuels and some liquids. We estimate an emission factor of 0.015 pounds of particulates per million BTU of fuel fired at the average refinery fired heater or boiler.

carbon dioxide

Carbon dioxide (CO_2) is a natural and necessary component of the atmosphere and is not a hazard to human health. However, it has been theorized that increased levels of CO_2 in the atmosphere can be detrimental to the environment, particularly by causing what is known as the greenhouse effect.

Carbon dioxide and water are produced when hydrocarbons are burned. Since it is a primary product in the combustion of hydrocarbons, the amount of CO_2 produced varies only with the quantity and type of hydrocarbon used. Control is possible only by decreasing firing rates.

A CO_2 emission rate can be determined by the estimated average carbon number of fuel burned at refinery furnaces.

TM&C estimates an average refinery emission factor of 125 pounds of CO_2 per million BTU of fuel fired.

ANALYTICAL BASIS

Ethyl Corporation (Ethyl) is requesting a waiver from EPA to allow refiners to use the performance additive HiTEC 3000 in unleaded gasoline. By providing up to a one octane number increase in unleaded gasoline, using HiTEC 3000 can significantly affect petroleum refinery operations. Ethyl retained TM&C to study the effect of HiTEC 3000 use on several aspects of refinery operations:

- Lower emissions from refinery furnaces;
- Lower hydrocarbon fugitive emissions from refinery process units;
- Conservation of crude oil;
- Beneficial changes in the hydrocarbon type of gasoline;
- Changes in butane production; and
- Decreasing long-term expensive process unit investments.

TM&C uses eight linear programming (LP) models and four simulators to represent the U.S. refining industry. These models were validated to a survey conducted by the National Petroleum Council (NPC) and have been extensively reviewed by refining industry advisory groups to NPC in 1985 and the American Petroleum Institute (API) in 1987. Two of these models, comprising 45% of U.S. gasoline production, have been used in this study of the effect of HiTEC 3000 use. The results have been extrapolated to the entire U.S. using results of TM&C's

earlier studies for NPC, API and a subscriber group of refiners.

model selection

Two of the eight TM&C U.S. refinery industry LP models were selected for this study. The IIIDC model represents thirty-three deep conversion refineries in Petroleum Administration Defense District (PADD) III. These refineries have coking capacity or capability to convert at least 50% of their vacuum bottoms to lighter products as well as catalytic cracking or hydrocracking capacity. They average 170 thousand barrels per stream day (MBPSD) of crude distillation capacity and collectively represent 5,629 MBPSD of crude capacity, or 34% of the U.S. refining industry. The IIIDC refineries are listed in Table 1. The other model, IC, represents the eleven conversion refineries in PADD I. All of these refineries have catalytic cracking or hydrocracking. They average 116 MBPSD of crude capacity for a total of 1,274 MBPSD of crude distillation capacity. This model was selected as being representative of refineries in the critical Philadelphia air shed region. The refineries represented by the IC model are listed in Table 2. Detailed process unit capacities for both models are compared to the U.S. total in Table 3.

A 1994 time frame has been studied. This provides ample time for EPA consideration of Ethyl's waiver request and refining industry reaction in terms of modified operations and construction schedules.

cases

Three 1994 cases were studied on each model:

- Base case;
- Severity reduction case; and
- Investment reduction case.

The base case was used to establish facilities investments and raw materials required to meet projected petroleum product rates and qualities. In the severity reduction case, base case investments were assumed to be in place, and HiTEC 3000 was allowed in all three grades of unleaded gasoline. The investment reduction case was designed to start with existing equipment plus under-construction facilities to determine the lowest future investments required to meet 1994 requirements if refiners could be assured of long-term permission to use HiTEC 3000 in unleaded gasoline.

demand

U.S. petroleum products demand has increased at a rapid rate of 2.3% per year since 1984, as shown in Table 4. Motor gasoline and distillate fuel have increased at about the average rate. However, kerosene type jet fuel has increased at a much faster rate of almost 7% per year. Residual fuel demand has been almost constant. The TM&C outlook for the next five years is based on a growth rate of only 1.2% per year. Resulting product demands projections are shown in Table 5.

supply

U.S. crude production has decreased by about 0.7 million barrels per calendar day (MMBPCD) since 1984. Further declines to about 6.85 MMBPCD are anticipated by 1994. This will mean that about 7.32 MMBPCD of crude imports will be required by 1994 compared to 5.1 MMBPCD in 1988. A complete 1994 U.S. supply and demand balance is shown in Table 6, with a crude oil breakdown for models IC, IIIDC and the U.S. shown in Table 7.

gasolines

TM&C's gasoline grade forecast is compared to actual grade splits since 1970 in Table 8. Premium unleaded market share has been growing at a rate of nearly 3% per year for the past two years. We expect this growth rate to gradually moderate. Unleaded premium should ultimately level off at about 35% of the gasoline pool. Other forecasters show at least 30% premium. However, TM&C believes that prudent refiners will plan for an ultimate level of 35% unleaded premium gasoline. The growth curve will not be as smooth as our forecast. There will be dips in the trend such as the one in the spring of 1989 when the rapid gasoline price run-up slowed the demand for premium.

Unleaded mid-grade gasoline is forecast to attain a profitable 15% market share even though it is neither the "best" nor the "cheapest". Industry experience indicates that the hoopla of introduction attracts an initial market of 15% to 20% at individual stations. In the long run, however, sales moderate. As leaded regular eventually declines to off-road use of about 3%, most three-pump service stations should parallel this individual station experience, and unleaded mid-grade should settle at about a 15% market share. TM&C believes that a U.S. average level higher than 20% is unlikely and below 10% would not be economically sustained.

Experience indicates that mid-grade supplants mostly unleaded regular. Most premium buyers want the best and are willing to pay for it. Perhaps motorists whose vehicles do poorly on regular go to mid-grade to improve performance. This should leave unleaded regular with an ultimate 47% share of the market, in TM&C's opinion.

With these ultimate figures in mind, TM&C forecast the following grade splits for 1994:

	%
Unleaded Regular	49
Unleaded Mid-Grade	14
Unleaded Premium	34
Leaded Regular	3

specifications

TM&C anticipates a continued shift from 92 to 93 octane premium in most of the U.S. Octanes will be slightly higher in some areas, such as the East Coast, and lower in other areas, such as the Midwest. Because of altitude effects, octane is usually two numbers lower in the Rocky Mountain area. As a result, U.S. average unleaded premium octane is expected to average 92.6 in 1994, as shown on Table 9. Unleaded regular is projected to continue to be at 87.1 octane. With the increase in premium octanes, mid-grade octane should also go up and average about 89.5 for the U.S. Leaded regular octane should continue its slow decline and reach about 88.2 by 1994. With almost half of PADD III gasoline production going to PADD I, predominantly from deep conversion refineries, TM&C's projected octane demands and grade splits for the IIIDC and IC models are also shown in Table 9. Summertime EPA Phase 2 RVP restrictions are estimated to reduce U.S. annual average RVP to 10.3 psi.

Further, TM&C has assumed that 0.05% sulfur limits for diesel will be promulgated by EPA. In this case, all of PADD I No. 2 fuel oil and diesel will meet this specification in 1994. Some PADD III refineries will not be able to economically produce the very low sulfur diesel fuel and will supply the higher sulfur off-road market. On the average TM&C estimates that 10% of PADD III No. 2 fuel will be produced to the higher 0.25% sulfur specification.

pricing

Raw material and product prices used in this study are shown in Table 10. Crude pricing is based on an $18 per barrel FOB OPEC basket of crudes with a corresponding $19.50 per barrel for WTI at Cushing. Product pricing is derived from TM&C's pricing models which are based on historic price relationships between clean products. We expect the price of 3% sulfur No. 6 fuel (bunker) at only $13 per barrel because of a worldwide surplus.

investments

Investments for new process units are based on typically sized units for the regions. This approach avoids overstating investment costs for small process additions in LP models. Costs are estimated in terms of 1989 dollars. The models were allowed to consider investments in octane improvement, desulfurization and resid upgrading processes but not in crude distillation and cracking. TM&C projects that 1994 product demands will justify these types of facility investments. TM&C pricing outlook will not justify new cracking unit investments, and crude unit investments are not required. In the IC model, only the octane and desulfurization options were considered due to the difficulty of gaining environmental approval for new coking units.

octane response

Octane gains from using HiTEC 3000 depend on the octane number and hydrocarbon type of the base gasoline as well as manganese concentration. Ethyl is asking for a waiver for the use of HiTEC 3000 at 0.03125 grams of manganese per U.S. gallon (gms Mn/USG) in all unleaded gasoline (8.3 milligrams Mn per liter). TM&C estimates that this will result in octane gains of 0.9 and 0.6 in typical 1994 unleaded regular and premium, respectively. As shown in Table 11, this will result in estimated octane improvement costs of 8¢ to 12¢ per octane number barrel (ONB) at current HiTEC 3000 prices. Since this is well below current and projected 1994 octane improvement costs of about 30¢ to 60¢/ONB, TM&C has assumed that HiTEC 3000 will be used in all unleaded gasoline if the waiver is granted.

flexibility

TM&C allowed residual fuel, coke, liquefied petroleum gas (LPG) and plant fuel to vary. Gasoline demand was optimized in the base cases and fixed at this level in subsequent cases. All other products were fixed at projected 1994 demands. Swing crudes were Arabian light and heavy with all other crudes fixed at projected levels for the IC and IIIDC models. Methanol for feed to the refinery methyl tertiary butyl ether (MTBE) unit and iso- and normal butane purchase rates for alkylation and gasoline blending could also be determined by the model. MTBE supplies from the merchant market were determined in the base case and fixed at this level in the other two cases. All other raw materials were fixed at projected availabilities.

RESULTS

BASE CASE

material balances

Projected raw material and product slates for the two refinery groups and total U.S. are shown in Tables 12 and 13. Crude rates of 1,134 MBPD and 5,009 MBPD were required to load the crude units to maximum capacity on a calendar day basis. The IC model required purchase of 12 MBPD of MTBE to meet octane quality requirements, and this amount was fixed in subsequent runs. MTBE to IIIDC was set at 35 MBPD in all cases, based on estimated availability. Gasoline production was allowed to optimize, and 698 MBPD and 2,712 MBPD were produced in IC and IIIDC, respectively. This was within the scope of our estimate for the demand on these groups of refineries. This gasoline volume was fixed in subsequent cases.

operations

Process unit utilizations are shown in Table 14. Most units are loaded to the maximum of 86% of stream day capacity (89% for crude units). TM&C feel that this is the highest level that can be sustained on an average year-round basis. The catalytic crackers operate at about 77% conversion, and 75% to 84% of them use high octane catalyst, near the maximum 85% that we allowed. The poly plants are forced to run at near maximum rate since they are located at refineries with limited or no alkylation capacity. Likewise, hydrogen plants are forced to run close to maximum rates because they are located at refineries that are otherwise significantly deficient in hydrogen.

investments

New capacity required to meet 1994 product rate and quality demands is shown in Table 15. In both models, distillate HDS units are required to meet the 0.05% sulfur specification on diesel fuel. In IIIDC, additional coker capacity is an economical way to upgrade inexpensive resid to middle distillate and gasoline with the help of other process units. Various combinations of octane improvement and gasoline producing processing will be required to meet 1994 quality and demand. We have included cat reformer improvements to upgrade some units by lowering operating pressure. Also included are the gasoline component butane fractionation and butane handling facilities required to meet EPA's Phase 2 RVP proposal.

HiTEC 3000 CASES

material balances

Changes in material balances from the base cases when HiTEC 3000 is used in unleaded gasoline are shown in Table 16. Generally, there are decreases in both Arab light and heavy crudes. There are modest changes in methanol and butane requirements. In the IC reduced investment case, methanol use is decreased reflecting lower refinery MTBE production. The product reductions are generally spread over all the products that were allowed to vary for flexibility. The IIIDC reduced investment case is somewhat different than the other cases. The model chose to continue to run crude oil at the maximum capacity. In addition, it chose to increase residual fuel and decrease coke, propane and plant fuel production by decreasing coker capacity.

This is a logical move for a refiner that is no longer struggling as hard to make gasoline and octane.

operations

Changes in process operations are shown in Table 17. These decreases reflect the material balance changes and an easing of octane requirements from processing. Crude oil processing decreases in the reduced severity cases are equivalent to conservation of 82 MBPCD of crude oil for the entire U.S. refining industry. Naphtha hydrotreater and reformer throughput and octane severity are decreased in all cases. Alkylation decreases, but this is sometimes offset by polymerization increases. In the reduced investment cases, a decrease in refinery MTBE production is indicated. Coker feed rates are reduced in three of the four cases.

emissions

Because of the use of HiTEC 3000 in unleaded gasoline, operating severity can be reduced at a variety of process units. This will result in reduced firing rates in refinery furnaces and boilers. Base case emissions and decreases for the HiTEC 3000 cases are shown in Table 18. Generally, the reduced severity cases indicate that the use of HiTEC 3000 will decrease refinery emissions by about 2.1%. Decreases in emissions in the reduced investment cases are nearly as great at about 1.6%.

investments

The reduced investment cases provide an estimate of decreased facilities requirements if refiners can be assured of long-term acceptance of the use of HiTEC 3000 in unleaded gasoline. Results shown in Table 19 indicate a general reduction in octane processing requirements. As expected, conventional low pressure (200 psi) unit investments will be decreased in this situation. Also, refinery MTBE production backs away from the use of all available iso-butylene. The decrease projected to the entire U.S. refining industry will add up to $730 million.

fugitive emissions

Volatile organic compounds (VOC) are emitted from pump and compressor seals, valves, flanges and other refinery process unit equipment. These fugitive emissions occur from both "leaking" and "nonleaking" equipment. EPA has established average fugitive emission factors for the synthetic organic chemicals manufacturing industry. Since there is no difference in physical equipment between the base case and the reduced severity case, there is no difference in estimated fugitive emissions between these two cases. The reduced investment case does represent a decrease in refinery equipment. For these cases, estimated fugitive emissions are reduced as follows:

	tons per year
Model IC	300
Model IIIDC	320
Total U.S.	1,300

gasoline quality

Gasoline pool composition and qualities for models IC and IIIDC are shown in Tables 20 through 23. Clear octane of the gasoline pool can be decreased by 0.76 octane number if HiTEC 3000 is used in all unleaded gasoline. This allows changes in process operation and blending that, in turn, result in decreases of aromatics, including benzene, in the gasoline pool. Details of hydrocarbon type changes are shown in Table 24. Overall reductions of 1.2% aromatics and about 0.1% benzene are indicated for the U.S. average for the severity reduction cases. In the reduced investment cases, decreases in aromatics and benzene average 1.0% and 0.1%, respectively. Slight increases in average olefin content are indicated in both scenarios. MTBE content decreased slightly in the IC cases because we have not considered a mandatory oxygenate program in this study. RVP stayed at the maximum allowed in all cases, and there were only minor changes in other volatility measurements.

butane balances

The use of HiTEC 3000 in unleaded gasoline will allow changes in process unit severities, principally reduction in reformer severity. The process units will produce less butane, but purchases will vary to meet processing and gasoline blending requirements. Normal butane balances for the two models are shows in Tables 25 and 26.

In Model IC, normal butane purchases are limited by supply availability. Productions from each refinery process are shown. Alkylate production indicates some diversion of iso-butane and butene to blending butane. Sales of butane are based on summertime surpluses due to the Phase 2 EPA RVP limits.

In Model IIIDC, butane purchases are variable, reflecting adequate supply. Sales are based on summertime RVP limits. In this model, some butane is blended to JP-4 jet fuel.

These normal butane balances reflect complete debutanization of gasoline components and typical recovery of butane. In actual practice, refiners leave some butane in gasoline components.

TABLE 1

REFINERY MODEL GROUP IIIDC

PADD III – DEEP CONVERSION REFINERIES

State	Company	City	Crude Distillation MBPSD
Alabama	Hunt	Tuscaloosa	35
Louisiana	BP (Sohio/Gulf)	Belle Chasse	205
	Citgo/PDVSA	Lake Charles	330
	Conoco	Lake Charles	164
	Exxon	Baton Rouge	474
	Mobil (Tenneco)	Chalmette	155
	Murphy	Meraux	95
	Placid	Port Allen	50
	Shell	Norco	220
	Star Enterprises (Texaco)	Convent	240
Mississippi	Amerada Hess	Purvis	32
	Chevron	Pascagoula	310
New Mexico	Bloomfield (Plateau)	Bloomfield	18
Texas	Amoco	Texas City	415
	Chevron (Gulf)	Port Arthur	418
	Coastal	Corpus Christi	95
	Crown Central	Houston	103
	Diamond Shamrock	Sunray	102
	Diamond Shamrock	Three Rivers	47
	El Paso (Texaco)	El Paso	23
	Exxon	Baytown	517
	Fina	Big Spring	60
	Fina	Port Arthur	110
	Hill (Charter)	Houston	69
	Koch	Corpus Christi	130
	LaGloria/Texas Eastern	Tyler	49
	Lyondell (ARCO)	Houston	314
	Marathon	Texas City	74
	Mobil	Beaumont	290
	PDVSA (Champlin)	Corpus Christi	160
	Phillips	Borger	110
	Phillips	Sweeny	195
	Valero	Corpus Christi	20
	Total (33 Refineries)		5,629

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TABLE 2

REFINERY MODEL GROUP IC

PADD I – ALL CONVERSION REFINERIES

State	Company	City	Crude Distillation MBPSD
Delaware	Star Enterprises (Texaco)	Delaware City	150
New Jersey	Amerada Hess	Point Reading	*
	Coastal (Texaco)	Westville	115
	Exxon	Linden	125
	Mobil	Paulsboro	104
Pennsylvania	Atlantic R&M (ARCO)	Philadelphia	130
	BP Oil (Sohio)	Marcus Hook	180
	Chevron (Gulf)	Philadelphia	180
	Sun	Marcus Hook	175
	United Refining	Warren	62
Virginia	Amoco	Yorktown	53
	Total (11 Refineries)		1,274

* FCC and alkylation only.

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TABLE 3

REFINERY PROCESS UNIT CAPACITIES DETAIL

1994 BASE[1]

(MBPSD)

	IC	IIIDC	U.S. Total
Feed Rate			
Crude – Atmospheric	1,274	5,629	16,318
Crude – Vacuum	607	2,350	7,085
Catalytic Cracking	607	2,050	5,347
Hydrocracking	70	433	1,238
Coking – Delayed	35	596	1,344
Coking – Fluid	46	36	200
Combined	81	632	1,544
Combined Coke – FOE	21	153	353
Thermal Cracking, Visbreaking	10	46	176
Solvent Deasphalting	26	158	275
Catalytic Reforming			
Continuous Regeneration	86	206	543
Low Pressure	76	713	1,393
High Pressure	191	549	1,991
Total	353	1,468	3,927
Hydrotreating			
Naphtha	394	1,466	4,113
Distillate	382	1,171	2,938
Heavy Gas Oil	124	655	1,731
Residuum	-	279	322
Product Rate			
Alkylation	77	418	1,019
Polymerization	17	31	97
Isomerization – C_5/C_6	25	111	334
Isomerization – C_4	4	13	72
Hydrogen – MMCFPSD	110	983	2,576
Hydrogen, FOE – MBPSD	6	50	131
Asphalt	71	115	823
Lube	19	82	230
Aromatics	19	173	287
Hydrodealkylation	7	19	39
MTBE	3	18	25
Sulfur, MLT/D	0.9	8.6	23.2

[1] 1/1/89 existing (DOE-*PSA*) plus under construction 2/89 *Hydrocarbon Processing*.

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TABLE 4

U.S. PRODUCT DEMAND GROWTH RATE

ACTUAL AND TM&C OUTLOOK

(% change/year)

	Actual 1988 vs. 1984	Outlook 1994 vs. 1988
Motor Gasoline	2.3	0.8[1]
Jet – Naphtha	(1.0)	0.0
Jet – Kerosene	6.9	2.7
Distillate Fuel	2.3	1.2[2]
Residual Fuel	0.2	1.3
LPG	1.4	1.0
Other Products	2.4	1.6
Total	2.3	1.2

[1] Gasoline growth rate outlook detail is 1.4% for 1989, 1.0% in 1990-91 and 0.5% in 1992-94.

[2] Distillate growth rate outlook detail is 1.5% in 1989-92 and 0.5% in 1993-94.

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TABLE 5

U.S. PRODUCT DEMANDS

ACTUAL AND TM&C OUTLOOK

(MMBPCD)

	Actual					Outlook					
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Motor Gasoline	6.69	6.83	7.03	7.21	7.34	7.44	7.51	7.59	7.63	7.67	7.70
Jet – Naphtha	0.22	0.21	0.20	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Jet – Kerosene	0.95	1.01	1.10	1.18	1.24	1.27	1.30	1.34	1.37	1.41	1.45
Distillate Fuel	2.85	2.87	2.91	2.98	3.12	3.17	3.22	3.26	3.31	3.33	3.35
Residual Fuel	1.37	1.20	1.42	1.26	1.38	1.40	1.41	1.43	1.45	1.47	1.49
LPG	1.57	1.60	1.51	1.61	1.66	1.68	1.71	1.74	1.74	1.75	1.76
Other Products	2.08	2.01	2.11	2.22	2.29	2.33	2.36	2.40	2.44	2.48	2.52
Total	15.73	15.73	16.28	16.67	17.24	17.50	17.72	17.97	18.15	18.32	18.48

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TABLE 6

U.S. SUPPLY AND DEMAND

1994 TM&C FORECAST – MMBPCD

	Supply			Demand		
	Field Production	Imports	Refinery Production	Refinery Input	Exports	Demand Products
Crudes						
Domestic	6.90	-	-	6.85	0.05	-
Foreign	-	7.32	-	7.32	-	-
[Total Crudes]	[6.90]	[7.32]	[-]	[14.17]	[0.05]	[-]
Products – NGL/Unfinished						
Natural Gasoline	0.30	0.01	-	0.06	-	0.25
Ethane	0.49	-	0.01	-	0.01	0.49
Propane	0.50	0.13	0.38	0.01	0.03	0.97
Normal Butane	0.17	0.08	0.11	0.13	0.01	0.22
Iso-Butane	0.14	0.06	-	0.12	-	0.08
Unfinished	-	0.35	-	0.54	-	(0.19)
Mogas Components	-	0.10	-	0.14	-	(0.04)
Oxygenates and Other	0.15	0.02	-	0.17	-	-
[Total NGL/Unfinished Products]	[1.75]	[0.75]	[0.50]	[1.17]	[0.05]	[1.78]
Products – Finished						
Motor Gasolines	0.07	0.37	7.28	-	0.02	7.70
Aviation Gasolines	-	-	0.03	-	-	0.03
Naphtha Jet	-	-	0.21	-	-	0.21
Kero Jet/Kerosene	-	0.20	1.38	-	0.03	1.55
Distillate Fuels	-	0.40	3.02	-	0.07	3.35
Residual Fuels						
<0.3% Sulfur	-	0.24	0.08	-	-	0.32
0.3-1.0% Sulfur	-	0.22	0.16	-	-	0.38
>1.0% Sulfur	-	0.27	0.72	-	0.20	0.79
[Total Residual Fuels]	[-]	[0.73]	[0.96]	[-]	[0.20]	[1.49]
Petrochem Naphtha	-	0.04	0.22	-	0.01	0.25
Petrochem Gas Oil + Carbon Black	-	0.01	0.17	-	0.01	0.17
Special Naphtha/Miscellaneous	-	0.01	0.16	-	0.01	0.16
Lube and Wax	-	0.01	0.20	-	0.03	0.18
Marketable Coke – FOE	-	-	0.43	-	0.32	0.11
Catalytic Coke – FOE	-	-	0.22	-	-	0.22
Asphalt/Road Oil	-	0.03	0.46	-	-	0.49
Process Gas – FOE	-	-	0.79	-	-	0.79
[Total Finished Products]	[0.07]	[1.80]	[15.53]	[-]	[0.70]	[16.70]
Total Crudes and Products	8.72	9.87	16.03	15.34	0.80	18.48
(Gain)/Loss	-	-	(0.69)	-	-	-

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TABLE 7

REFINERY CRUDE INPUT RATES SUMMARY

1994 TM&C BASE CASE FORECAST RESULTS

(MBPCD)

	IC	IIIDC	U.S. Total
Domestic			
Sweet	-	840	2,970
High Sulfur Light	-	440	660
High Sulfur Heavy	25	330	3,220
Total	25	1,610	6,850
Foreign			
Sweet	639	770	2,230
High Sulfur Light	132	642	1,740
High Sulfur Heavy	338	1,987	3,350
Total	1,109	3,399	7,320
Combined			
Sweet	639	1,610	5,200
High Sulfur Light	132	1,082	2,400
High Sulfur Heavy	363	2,317	6,570
Total	1,134	5,009	14,170

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TABLE 8

U.S. GASOLINE GRADE MIX

ACTUAL AND TM&C FORECAST

(% of pool)

	Source	Unleaded			Leaded	
		Regular	Premium	Mid-Grade	Regular	Premium
Actual						
1970	Ethyl	-	3.0[1]	-	57.4	39.6
1975	Ethyl	10.0	3.0[1]	-	68.0	19.0
1980	Ethyl	35.2	8.0[1]	-	52.1	4.7
1984	DOE-PMA	42.8	14.1	1.5	0.9	0.7
1985	DOE-PMA	45.6	15.2	2.0[1]	37.2	-
1986	DOE-PMA	47.9	17.3	3.0[1]	31.8	-
1987	DOE-PMA	51.5	20.0	4.0[1]	24.5	-
1988	DOE-PMM	53.3	23.0	5.0[1]	18.7	-
Outlook						
1989	TM&C	56.9	25.8	7.3	10.0	-
1990	TM&C	57.5	28.2	9.3	5.0	-
1991	TM&C	56.0	30.2	10.8	3.0	-
1992	TM&C	53.2	31.8	12.0	3.0	-
1993	TM&C	51.0	33.0	13.0	3.0	-
1994	TM&C	49.0	34.0	14.0	3.0	-
Ultimate	TM&C	47.0	35.0	15.0	3.0	-

[1] TM&C estimate.

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TABLE 9

GASOLINE GRADE MIX AND QUALITIES

1994 TM&C OUTLOOK

	Unleaded			Leaded
	Regular	Premium	Mid-Grade	Regular
Grade Mix, %				
U.S. Average	49	34	14	3
IIIDC	47	38.5	13	1.5
IC	41	42	17	-
Octanes, (R+M)/2				
U.S. Average	87.1	92.6	89.5	88.2
IIIDC	87.1	92.8	89.6	88.6
IC	87.2	92.9	89.7	-
Reid Vapor Pressures, psi				
U.S. Average	10.3			
IIIDC	10.1			
IC	10.9			

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TABLE 10

TM&C PRICING OUTLOOK[1]

1990s GULF COAST

		¢/G	$/B
Major Products[2]			
Unleaded Regular Gasoline		56.0	-
Unleaded Premium Gasoline		62.0	-
Distillate Fuel (0.05% Sulfur)		54.5	-
Residual Fuel (Bunker)		-	13.00
Major Crudes[3]			
Domestic	– West Texas Intermediate	-	19.70
	– West Texas Sour	-	18.45
	– Alaska North Slope	-	17.65
Foreign	– United Kingdom Brent	-	19.50
	– Saudi Arabia Light	-	18.45
	– Saudi Arabia Heavy	-	16.75
Other			
MTBE		82.5	-
Methanol		60.0	-
Iso-Butane		42.5	-
Normal Butane		36.5	-
Propane		25.5	-
Natural Gas – FOE		2.30[4]	14.50

(1) Based on $19.50/B WTI crude at Cushing and the $18/B FOB OPEC crude basket.
(2) Pipeline lows.
(3) Delivered to Gulf Coast.
(4) $/MMBTU.

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TABLE 11

OCTANE IMPROVEMENT COSTS

1994 PROJECTION

	¢/ON Barrel	gm Mn/Gal.	(R+M)/2 Gain
HiTEC 3000			
Unleaded Regular	8[1]	0.03125	0.9
Unleaded Mid-Grade	9[1]	0.03125	0.8
Unleaded Premium	12[1]	0.03125	0.6
Processing, Base Cases			
IIIDC	38	-	-
IC	37	-	-
U.S.	30 to 60	-	-

[1] At 5.6¢/gm Mn.

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TABLE 12

REFINERY RAW MATERIAL RATES DETAIL

1994 TM&C BASE CASE FORECAST RESULTS

(MBPCD)

	IC	IIIDC	U.S. Total
Domestic Crudes	25	1,610	6,850
Foreign Crudes	1,109	3,399	7,320
Total Crudes	1,134	5,009	14,170
Natural Gasoline	-	17	60
Reformate – 100 RONC	36	20	140
Naphtha	5	70	120
Vacuum Gas Oil – HS	92	52	200
Vacuum Gas Oil – LS	92	53	205
Vacuum Resid – VHS	-	15	15
Normal Butane	3	82	130
Iso-Butane	2	74	120
MTBE	12	35	100
Methanol	5	16	35
Propane	-	5	10
Natural Gas Feed to H_2 FOE	1	36	35
Total	1,382	5,484	15,340

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TABLE 13

REFINERY PRODUCT RATES DETAIL

1994 TM&C BASE CASE FORECAST RESULTS

(MBPCD)

	IC	IIIDC	U.S. Total
Motor Gasolines			
Low Lead Regular	-	41	219
Unleaded Regular	286	1,274	3,567
Unleaded Intermediate	119	353	1,019
Unleaded Premium	293	1,044	2,475
Total	698	2,712	7,280
Aviation Gasolines	-	13	30
Naphtha Jet	15	42	210
Kero Jet/Kerosene	75	599	1,380
Distillate Fuels – 0.25%S	-	57	280
Distillate Fuels – 0.05%S	299	1,071	2,740
Residual Fuels			
<0.3% Sulfur	30	20	80
0.3-0.7% Sulfur	20	15	50
0.7-1.0% Sulfur	41	20	110
1.0-2.0% Sulfur	3	33	350
>2.0% Sulfur	10	25	370
Total	104	113	960
Asphalt/Road Oil	48	59	460
Marketable Coke – FOE	15	226	430
Benzene	2	30	40
Toluene	7	28	45
Xylene	-	40	55
Special Naphtha/Miscellaneous	10	-	160
Petrochem Naphtha	-	30	80
Lubes	15	66	185
Wax	-	1	15
Petrochem Gas Oil	-	10	130
Carbon Black Feed	-	21	40
Normal Butane	10	50	111
Propane	26	133	379
Plant Fuel	92	363	800
Catalytic Coke – FOE	23	86	220
(Gain)/Loss	(57)	(266)	(690)
Total Products	1,382	5,484	15,340
Sulfur, MLT/D	1.0	6.2	14.0

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TABLE 14

REFINERY PROCESS UNIT UTILIZATIONS[1]

1994 BASE CASE FORECAST RESULTS – %

	IC	IIIDC
Crude – Atmospheric	89.0*	89.0*
Catalytic Cracking[2]	86.0*	86.0*
Catalytic Cracking[3]	81.3	82.8
Conversion, %	77.9	76.9
Octane Catalyst, %	84.5	75.1
Hydrocracking	86.0*	86.0
Jet Yield, % of Maximum	100.0	100.0
Coking – Delayed[2]	86.0*	86.0*
– Fluid[2]	86.0*	86.0*
– Combined[3]	86.0*	86.0*
Thermal Cracking, Visbreaking	86.0*	86.0*
Solvent Deasphalting	86.0*	47.4
Catalytic Reforming – Continuous	86.0*	86.0*
RONC	102.0	101.2
– Low Pressure[2]	86.0*	86.0*
RONC	99.8	99.1
– High Pressure[2]	86.0*	86.0*
RONC	100.0	95.0
– Combined[3]	78.2	83.6
RONC	100.2	98.7
Hydrotreating – Naphtha	56.6	66.6
– Distillate	86.0*	86.0*
– Heavy Gas Oil	83.4**	86.0*
– Residuum	-	86.0*
Alkylation	69.1	86.0*
Polymerization	63.2**	74.3**
Isomerization – C_5/C_6	86.0*	86.0*
Isomerization – C_4	-	86.0*
Hydrogen	78.2**	77.4**
Asphalt	67.6	51.3
Lubes	80.9	80.8
Aromatics Extraction	86.0*	83.3
Hydrodealkylation	-	86.0*
MTBE	86.0*	86.0*
Sulfur, MLT/D	54.1	86.0*

* Limited at maximum throughput in LP run.
** Limited at minimum throughput in LP run.
– No unit.
(1) Calendar day rates divided by stream day capacity.
(2) Include effects of nonunitary capacity factors for some feedstocks and severities.
(3) Based on actual feed rates, ignoring severity effects.

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TABLE 15

1994 NEW CAPACITY AND INVESTMENT

REQUIRED FOR TM&C BASE CASE

	IC	IIIDC	U.S. Total[1]
New Capacity, MBPSD			
Coker, Delayed	-	302	361
Distillate HDS	18	548	1,280
Cat Reformer	-	38	106
MTBE	12	35	102
Alkylation	-	19	32
Fractionation[2]	11	249	664
Improvements, MBPSD			
Distillate HDS – Add Reactor	382	1,171	2,938
Cat Reformer – Reduce Pressure	96	274	952
Gasoline Stabilizers – Fractionation	136	254	812
Investment, MM$			
New Capacity	91	1,993	5,400
New Fractionation[2]	3	53	176
Improve Distillate HDS – LHSV	41	127	345
Improve Cat Reformer – Delta P	25	72	279
Improve Fractionation[2]	4	7	27
Improve C_4 Handling[2]	2	2	54
Total	166	2,254	6,281

[1] Extrapolated.
[2] RVP reduction survey for API.

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TABLE 16

1994 MATERIAL BALANCE CHANGES WITH HITEC 3000

DECREASES FROM BASE CASE

(MBPCD)

	IC		IIIDC	
	Reduced Severity	Reduced Investment	Reduced Severity	Reduced Investment
Raw Materials				
Arab Heavy Crude	8.5	1.8	26.0	-
Arab Light Crude	0.9	0.2	2.8	-
Methanol	0.1	3.6	(0.1)	0.6
Normal Butane	-	-	2.3	(1.7)
Iso-Butane	-	-	1.7	8.4
Total Raw Materials	9.5	5.6	32.7	7.3
Products				
Residual Fuel > 1% Sulfur	3.0	3.0	3.3	(26.7)
Marketable Coke	0.4	(0.1)	0.5	7.3
Propane	1.0	0.7	3.2	4.3
Plant Fuel Burned	2.3	0.2	16.4	18.7
Loss/(Gain)	2.8	1.8	9.3	3.7
Total Products	9.5	5.6	32.7	7.3

Note: Increases are shown in parenthesis as negative decreases.

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TABLE 17

1994 PROCESSING RATE CHANGES WITH HiTEC 3000

DECREASES FROM BASE CASE

(MBPCD)

	IC		IIIDC	
	Reduced Severity	Reduced Investment	Reduced Severity	Reduced Investment
Processing Rate Changes				
Crude	9.4	1.8	28.8	-
Coking – Delayed	-	-	1.6	25.9
Coking – Fluid	12.6	-	-	-
Solvent Deasphalter	-	-	18.0	35.4
Naphtha Hydrotreater	17.6	6.9	28.9	23.1
Distillate HDS	-	-	0.4	-
FCC Feed Hydrofiner	-	-	15.2	-
Cat Reforming – Effective[1]	3.0	24.2	71.5	70.6
Cat Reforming – Actual[2]	21.0	12.3	39.3	39.8
FCC	-	-	-	2.0
FCC Gasoline Splitter	17.4	(92.4)	-	-
Alkylation	1.3	4.4	0.8	15.9
Cat Poly	(4.0)	-	-	(3.6)
MTBE	-	10.5	-	1.9
Reformer RONC Decrease	1.4	1.0	1.6	1.5

Note: Increases are shown in parentheses as negative decreases.
[1] Includes effects of nonunitary capacity factors for some feedstocks and severities.
[2] Based on actual feed rates, ignoring severity factors.

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TABLE 18

REFINERY FURNACE EMISSIONS[1]

(tons per year)

	IC	IIIDC	U.S. Total
Base Case			
NO_x	21,200	101,000	260,000
CO	5,650	27,000	70,000
Particulates	2,100	10,100	26,000
SO_x	3,530	1,200	10,180
CO_2 (thousand tons per year)	17,600	84,300	217,000
Reduced Severity Cases With HiTEC 3000			
Decreased Emissions			
NO_x	400	2,200	5,500
CO	110	600	1,500
Particulates	40	220	550
SO_x	5	30	75
CO_2 (thousand tons per year)	340	1,900	4,800
Reduced Investment Cases With HiTEC 3000			
Decreased Emissions			
NO_x	50	1,900	4,200
CO	15	500	1,100
Particulates	5	200	440
SO_x	1	25	55
CO_2 (thousand tons per year)	40	1,600	3,500

[1] Does not include emissions from other refinery sources such as FCCU regenerator stacks, flares, coke drums, etc.

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11/14/89

TABLE 19

1994 NEW CAPACITY AND INVESTMENT WITH HiTEC 3000

DECREASES FROM BASE CASE

	Reduced Investment Cases	
	IC	IIIDC
New Capacity, MBPSD		
Coker, Delayed	-	30
Cat Reformer	-	38
MTBE	12	2
Alkylation	-	19
Improvements, MBPSD		
Cat Reformer – Reduce Pressure	96	-
Investment, MM$		
New Capacity	67	250
Improve Cat Reformer – Delta P	25	-
Total[1]	92	250

[1] Projected total U.S. refining industry investment decrease is $730 million.

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TABLE 20

GASOLINE POOL COMPOSITION

MODEL IC

(%)

	Base	HiTEC 3000 Cases Reduced Severity	HiTEC 3000 Cases Reduced Investment
FCC Gasoline	40.6	42.3	41.1
Reformate	30.8	29.8	30.3
Alkylate	7.6	7.4	8.2
Butanes	7.4	7.3	7.7
Isomerate	3.0	3.0	3.0
LSR Gasoline	2.9	2.9	2.9
Light Hydrocrackate	1.5	1.4	1.5
MTBE	3.6	3.5	2.1
Raffinate	-	0.8	0.7
Poly Gasoline	1.6	1.6	1.6
Toluene/Xylenes	1.0	-	0.9
Total	100.0	100.0	100.0

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TABLE 21

GASOLINE POOL COMPOSITION

MODEL IIIDC

(%)

		HiTEC 3000 Cases	
	Base	Reduced Severity	Reduced Investment
FCC Gasoline	35.4	35.6	35.5
Reformate	28.4	29.7	29.7
Alkylate	13.5	13.5	13.2
Butanes	6.9	6.8	6.8
Isomerate	3.5	3.5	3.5
LSR Gasoline	4.5	4.6	4.6
Light Hydrocrackate	2.1	2.1	2.1
MTBE	3.0	3.0	3.0
Raffinate	-	0.2	0.4
Poly Gasoline	0.9	0.8	1.0
Toluene/Xylenes	1.8	0.2	0.2
Total	100.0	100.0	100.0

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TABLE 22

GASOLINE POOL QUALITIES

IC 1994 TM&C RESULTS

		HiTEC 3000 Cases	
	Base Case	Reduced Severity	Reduced Investment
(R+M)/2 Octane As Shipped[1]	90.0	90.0	90.0
(R+M)/2 Octane, Clear	90.0	89.3	89.3
MTBE, %	3.6	3.5	2.1
Aromatics, %	33	32	32
Benzene, %	1.7	1.6	1.7
Olefins, %	17	17	17
Reid Vapor Pressure, psi	10.9	10.9	10.9
Temperature at V/L = 20, °F	129	129	129
Distillation, % at			
170°F	33	33	32
212°F	47	47	46
257°F	62	62	61
356°F	93	93	93

[1] With performance additive.

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TABLE 23

GASOLINE POOL QUALITIES

IIIDC 1994 TM&C RESULTS

	Base Case	HiTEC 3000 Cases Reduced Severity	Reduced Investment
(R+M)/2 Octane As Shipped[1]	89.6	89.6	89.6
(R+M)/2 Octane, Clear	89.6	88.9	88.9
MTBE, %	3.0	3.0	3.0
Aromatics, %	30	29	29
Benzene, %	1.7	1.6	1.5
Olefins, %	14	14	14
Reid Vapor Pressure, psi	10.1	10.1	10.1
Temperature at V/L = 20, °F	132	132	132
Distillation, % at			
170°F	35	34	34
212°F	49	48	48
257°F	63	63	63
356°F	93	94	94

[1] With performance additive.

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TABLE 24

HYDROCARBON TYPE DECREASE DETAIL

(% of gasoline pool)

	IC	IIIDC	U.S. Total
Reduced Severity Cases			
Benzene	0.16	0.09	0.1
Aromatics	1.4	1.2	1.2
Olefins	(0.5)	-	(0.1)
Reduced Investment Cases			
Benzene	0.04	0.15	0.1
Aromatics	0.7	1.1	1.0
Olefins	(0.3)	(0.2)	(0.2)

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TABLE 25

NORMAL BUTANE BALANCE

MODEL IC[1]

(barrels per calendar day per refinery)

	Base	HiTEC 3000 Cases Reduced Severity	HiTEC 3000 Cases Reduced Investment
Supply			
Purchase	273	273	273
Crude Distillation	1,151	1,139	1,149
Delayed Coker	47	47	47
Fluid Coker	75	72	75
Visbreaker	5	5	5
Cat Reformer – 450 psi	293	209	209
– 200 psi	237	236	239
– 100 psi (Continuous)	57	44	51
Fluid Cat Cracker	1,216	1,172	1,207
Hydrocracker	198	234	203
Alkylation Plant	120	117	130
Total	3,672	3,548	3,588
Disposition			
Sales	909	909	909
Gasoline Blends	1,932	1808	1,848
Refinery Fuel	735	735	735
Refinery Loss	96	96	96
Total	3,672	3,548	3,588
Gasoline RVP, psi	10.9	10.9	10.9

[1] Model IC represents eleven refineries.

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TABLE 26

NORMAL BUTANE BALANCE

MODEL IIIDC[1]

(barrels per calendar day per refinery)

		HiTEC 3000 Cases	
	Base	Reduced Severity	Reduced Investment
Supply			
Purchase	2,489	2,418	2,540
Crude Distillation	1,505	1,494	1,506
Delayed Coker	542	539	529
Fluid Coker	20	21	14
Visbreaker	7	7	7
Residual Hydrofiner	7	7	7
Cat Reformer – 450 psi	263	221	221
– 200 psi	602	557	534
– 100 psi (Continuous)	45	35	43
Fluid Cat Cracker	1,301	1,305	1,302
Hydrocracker	540	553	542
Alkylation Plant	288	284	277
Total	7,609	7,441	7,522
Disposition			
Sales	1,515	1,515	1,515
Gasoline Blends	5,640	5,450	5,531
JP-4 Blends	-	22	22
Butane Isomerization Feed	340	340	340
Refinery Loss	114	114	114
Total	7,609	7,441	7,522
Gasoline RVP, psi	10.1	10.1	10.1

[1] Model IIIDC represents 33 refineries.

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ATTACHMENT 6-2

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MEMORANDUM

in Response to the Department of Energy's

Notice of Inquiry on "Alternative Financing Methods for Funding

the Strategic Petroleum Reserve Supplies and Facilities"

We have submitted this memorandum for the Department of Energy's Notice of Inquiry on "Alternative Financing Methods for Funding the Purchase of Strategic Petroleum Reserve Supplies and Facilities." It was initially prepared and submitted to the Department of Energy at the request of Secretary James Watkins, who made the request of John Lichtblau, PIRINC's president, at Mr. Lichtblau's August 1, 1989 testimony on the National Energy Strategy. The memorandum was designed to provide broad background on the concept of SPR leasing, not a detailed evaluation of competing proposals.

October 17, 1989
New York City

* * * * * * * * * * *

The Need for Additional Supplies

The DOE projects a sustained increase through the end of the century in both the volume of U.S. oil imports and the share of imports in total U.S. oil supplies. Most forecasts by industry, academic analysts and independent research organizations agree with these trends, i.e. there is a wide consensus that for the next 10 years U.S. oil imports will rise substantially, both in volume and share. Since we are already at a 41-42% net import dependency level this year (compared to 27% only four years ago), the question of future security of supply takes on increasing importance.

The only instrument designed to mitigate the impact of a future oil disruption as well as provide a potential deterrent against its occurrence is the Strategic Petroleum Reserve (SPR). As our import dependency grows, so does the necessary volume for the SPR. At end-September 1989 our SPR amounts to 575 million bbls, equal to 79 days of this year's average net import level of 7.3 million B/D. This is substantially below the 90-day net import coverage target set by the previous Administration and approximately maintained in 1988.

If the Administration were to maintain a fill rate of 75,000 B/D until 1995, the SPR at the end of that year would be close to its target, but the import coverage will only be 78 days, based on the DOE's Base Case projection of 9.4 million B/D net imports in 1995. However, this year's rate will be at least 10,000 B/D lower, and in fiscal 1990 the appropriated funds will permit a fill rate of only about 50,000 B/D.

Recent Congressional hearings indicate that both Houses of Congress favor raising the SPR target to 1 billion bbls, accelerating the current fill rate and, if possible, returning the SPR to the 90 days' import coverage ratio. However, both Houses recognize the fiscal constraints on all of these otherwise desirable goals. This has given rise to inquiries into alternative means of financing the increases in volume and fill rate. One such alternative -- leasing the oil for a fee from a foreign producer -- is discussed below.

It should be pointed out that the additional quantities are not only limited by budgetary constraints but also by physical limitations. If only existing storage facilities or those under preparation are considered, the total fill rate during the next several years could probably not exceed 125-130,000 B/D. Thus, incremental supplies could not exceed 50-55,000 B/D during this period. At present market prices, the annual delivered cost of this volume would be $380-400 million. However, it may be possible to increase the salt dome storage capacity beyond those included in the current 750 million bbl target program. At a hearing before the Senate Committee on Energy and Natural Resources, The Louisiana Land and Exploration Company offered to lease a salt dome with a storage capacity of 300 million bbls to the SPR. The Company estimated that it could start filling the facility within 3 years after the leasing commitment and could have up to 250 million bbls in place 4 years after starting to fill. Thus, if the commitment to lease this facility, or a similar one, were to be made next year, we could have an SPR volume of up to 1 billion bbls in place by 1997, if so desired.

Foreign Supplier's Participation

Foreign supplier participation in whatever fill rate increase the Administration sets would be based on the following assumptions and observations.

1. Because of budgetary constraints, the U.S. government is not able to buy the desired incremental volumes of SPR oil at market prices.

2. Unless alternative financing can be arranged, the volumes in question will not be lifted but will remain in the foreign producer's ground.

3. The oil procured under these participation arrangements will not normally enter commercial channels but will remain part of the U.S. Government's emergency reserve, to be used only after an official finding that a energy emergency exists which requires remedial action.

4. The economic interest of foreign oil producing countries in entering a leasing agreement for incremental SPR supplies would be directly proportional to these countries' excess producing capacity and the reserves underlying it. Only producing countries with significant excess producing capacity and the expectation of long-term maintenance of this excess would have an economic interest in participating in any arrangement under which they would let go of some oil below current market value. Their interest in doing so is strengthened if their reserves are of such magnitude that the extra oil produced now for non-commercial purposes would not be produced commercially until the depletion of their reserves sometime in the distant future. The more distant that future, the lower the discounted present value of the extra production.

Thus, the type of leasing agreement discussed here is based on a convergence of interests between buyer and seller: the U.S. government wishes to procure incremental volumes of crude oil for non-commercial purposes and cannot pay the commercial market price for these incremental volumes. The supplier can provide this oil from his unused surplus which would otherwise remain in the ground and earn no money for a very long time.

Since a leasing scheme would be economically attractive only for oil exporters with excess producing capacity, most potential participants in such a scheme would be members of OPEC whose designated production quotas are below their productive capacity. Hence, Mexico, currently the sole supplier of oil for the SPR, would have no economic interest in a leasing arrangement. However, it may have a political interest, such as protecting its supplier status to the SPR. There are reports that Norway, which has a self-imposed excess production margin of 7.5 %, has expressed interest in a leasing arrangement.

Under OPEC's definition, crude oil production is not counted as part of a country's quota until it enters commercial channels; oil produced for storage is not counted as quota production until it is sold or otherwise transferred to a third party. Thus, OPEC oil produced for *leasing* to the SPR would be outside the quota as long as the producing country retains ownership. Nevertheless, leases to the U.S. SPR could be controversial within OPEC.

In contrast to leasing, the OPEC definition of production quotas may make members of the group unwilling to consider another means of alternative financing of incremental SPR supplies, namely simply *selling* the oil to the SPR below the going market price. Since the oil would no more enter the commercial market whether it is sold or leased to the SPR, a sales price substantially below market value but well above production cost could benefit both parties. But it would be a clear violation of the OPEC quota definition. Also, as the SPR purchase price becomes known, commercial buyers may view it as a target price for their purchases.

Leasing Arrangements

The actual leasing agreement would of course be subject to extensive negotiations on all aspects of the arrangement. Two basic requirements on the U.S. side would be that the oil is physically deposited in the Government's designated SPR facilities and can be used at the Government's discretion. A basic requirement for the lessor country would be assurance that the oil would not enter into commercial channels except under the extraordinary pre-defined conditions requiring activation of the SPR.

There is no specific formula to establish a leasing fee because of the many factors and considerations that enter into it, all of them requiring lessor - lessee negotiations. For discussion purposes, one approach to consider would have the U.S. Government reimburse the lessor for the actual cash cost of lifting and transporting the oil and the foregone interest on the money spent. This would amount to a fraction of the market price. The negotiated annual leasing fee after this initial payment would represent a net positive cash flow at any level for the lessor, incremental to all earnings from commercial sales.

Another approach to the leasing fee would have the Government pay an annual leasing fee equivalent to an interest rate on the cost of buying the oil at market prices. If the interest rate is below the U.S. Treasury Bond rate, lease payments would be lower than the combined cost to the Government of purchasing the oil at market price and paying the going interest on the borrowed funds, provided the lease payments cease, with the leased oil possibly becoming U.S. Government property, as the cumulative payments approach the market value of the oil. The termination terms would have to be stipulated in the contract.

Another issue to be contractually agreed is the transfer terms of the leased oil if the SPR is activated, since the market price will be abnormally high at that time. Giving the foreign lessor the full spot market value at that time might be considered excessive since the U.S. Government will already have made previous fee payments and provides the storage facilities. There could also be political criticism if a foreign producer were to earn a large windfall profit during a crisis from the sale of oil stored in the SPR, even though the accumulation of the leased SPR oil would presumably keep the crisis price increase lower than it would be otherwise. Thus, the contract should contain a formula to determine the transfer price of leased oil following activation of the SPR's draw-down function.

Non-Economic Factors

In assessing the producing countries' interest in leasing arrangements with the U.S. SPR we have limited ourselves to the economic aspects of the arrangements. However, there is also a political dimension. By cooperating with the U.S. on a scheme to supply the SPR with incremental oil below market value, a supplier country in effect takes a position against any form of disruption which would create a price spike. This could earn the foreign supplier political "good will" in the U.S. which is an intangible but real asset. For some foreign suppliers the "good will" aspect of an SPR leasing scheme may outweigh the economic aspect.

The "good will" aspect may also motivate some foreign oil *importing* countries (possibly Japan) to participate in an SPR leasing scheme. In that case the foreign country would probably purchase the oil at market prices and then lease it to the SPR. If the leasing rate is below the prevailing interest rate of U.S. Treasury bonds, such a scheme could be of interest to the U.S. government. As part of the arrangement the foreign country may want to have access to a predetermined share of the leased oil in our SPR, perhaps on a swap basis, in case of an oil disruption requiring activation of the SPR. The lower cost of salt dome versus steel tank storage could be a factor in the foreign country's interest in having access to SPR facilities.

Appendix 7

APPENDIX 7

TOTAL POLLUTANT REDUCTION

I. SUMMARY

Use of the HiTEC® 3000 Performance Additive ("HiTEC 3000") in unleaded gasoline results in a substantial reduction in the emission of total air pollutants. Automobiles fueled with unleaded gasoline containing the HiTEC 3000 additive emit less nitrogen oxides (NOx), carbon monoxide (CO), aromatics such as benzene, and other noxious compounds such as formaldehyde. In addition, because the HiTEC 3000 additive increases the octane of unleaded fuel, refineries can produce gasoline under less severe conditions. As a result, refineries emit less NOx, CO, sulfur oxides, carbon dioxide, particulates, and under certain circumstances, fewer fugitive volatile organic compounds.[1] Combining the reductions from all sources, use of the HiTEC 3000 additive will reduce regulated air pollutant emissions by up to approximately 1.7 billion pounds per year by 1999 as shown in the following table.

TOTAL POLLUTANT REDUCTION -- USE OF THE HiTEC 3000 ADDITIVE
(Thousand Pounds Per Year)

Pollutant	1999
Nitrogen Oxide	644,000
Carbon Monoxide	988,000
Hydrocarbons	------[2]
Particulates	1,100
Sulfur Oxides	150
Aromatics	35,200
Formaldehyde	3,500
Total	1,671,950

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[1]These are emitted from pump and compressor seals, valves, flanges and other refinery processing equipment. See Appendix 6, Attachment 6-1.

[2]The total pollutant reduction does not include the calculated 63 million pounds per year increase due to hydrocarbon emissions from our fleet test data. Petroleum and automotive industry sources have published information that depicts a relationship between the aromatic content of gasoline and HC tailpipe emissions -- i.e., as aromatic content decreases, HC tailpipe emissions decrease (See Appendix 9). This is important because use of the HiTEC 3000 additive will allow refiners to reduce the aromatic content of gasoline (See Appendix 6, Attachment 6-1). This reduction in the aromaticity of the

II. Methodology

To estimate the extent to which the HiTEC 3000 additive reduces total air pollutants, some broad assumptions were used. Since the HiTEC 3000 additive has a long-term emission reduction effect, the estimated results discussed in this appendix will be for the year 1999. Ethyl Corporation ("Ethyl") selected the year 1999 for two reasons. First, there is information available for 1999 on total estimated Volatile Organic Compounds (VOC) emissions and total Nitrogen Oxide (NOx) emissions.[3] Second, while substantial emission reductions will occur each year leading up to 1999, the year 1999 provides a measure of the full emission benefits that can be achieved through use of the HiTEC 3000 additive.

It is also necessary to make projections and assumptions regarding the population and other characteristics of the U.S. automobile fleet. In this regard, Ethyl obtained all actual automobile data discussed in this appendix from the Motor Vehicle Manufacturers Association publication Facts & Figures '89.

The car population discussed in this appendix always refers to cars in operation as opposed to total registrations. Cars in operation represent those automobiles that are still physically accumulating mileage, while total registrations include automobiles that are still registered but inactive for various reasons. In 1988, as of July 1, there were 121.5 million automobiles in operation.[4] In order to estimate total cars in operation in future years, a linear regression line was fit to the existing data for years 1976 to 1988 (Attachment 7-1). In this model, total cars in operation are projected to increase from 121.5 million in 1988 to 141.4 million by 1999.

The emission test data for Ethyl's fleet test program were

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gasoline made possible by use of the HiTEC 3000 additive should, in turn, lead to a reduction in HC tailpipe emissions, offsetting the slight HC emission increase exhibited in the test cars using fuel containing the HiTEC 3000 additive. Even if the small HC increase observed in the test program was taken into account, however, total pollutant reductions would still be in excess of 1.6 billion pounds per year. See infra at page 5.

[3] Catching Our Breath -- Next Steps for Reducing Urban Ozone, Office of Technology Assessment, United States Congress, July 1989.

[4] Facts & Figures '89, Motor Vehicle Manufacturers Association, 1989, p. 28.

obtained on 1988 model automobiles which are all equipped with three-way catalyst emission systems.[5] For analysis purposes, Ethyl has assumed that all automobiles since Model Year 1981 are equipped with three-way emission control systems. It is further assumed that all automobiles with three-way type emission control systems will react to the HiTEC 3000 additive like the 1988 automobiles in Ethyl's fleet test program, and that automobile manufacturers will continue to employ three-way catalyst emission control systems to meet applicable emission control standards.

To estimate the total number of automobiles in operation for the years 1989-1999, Ethyl employed three groupings of model year time frames. These three groupings are Pre-1975, 1975-1980, and Post-1980. Ethyl estimated the decline in the Pre-1975 models and 1975-1980 models by regression analysis using actual data for years 1976 to 1988 along with some manual adjustment to reflect a slowdown in actual scrappage rates of older cars. Ethyl estimated the number of Post-1980 automobiles by regression using 1981 to 1988 actual data with a gradual tapering off in years 1994 and beyond due to scrappage of the older cars in this category (1981-1984,etc.). Estimates of the number of cars in operation by year and model category are shown in Attachment 7-2. Ethyl estimated the total number of automobiles for years 1989-1999 from the curve shown in Attachment 7-1 while the individual categories add up to the total for each year.

III. <u>1999 Case</u>

For the 1999 case, Ethyl assumed that the HiTEC 3000 additive was introduced into all unleaded gasoline in 1991 and that all automobiles in operation will be equipped with three-way catalyst systems. From Attachment 7-3, it can be determined that 51.4% of the automobiles on the road at anytime are at some mileage point between 0 and 78,000 miles and represent 59% of the total miles driven. Also, the remaining 48.6% of the automobiles have over 75,000 miles and represent 41% of the total miles driven.

For purposes of this analysis, the HiTEC 3000 additive effect used for cars less than six years old is the average effect obtained over the <u>entire</u> 75,000 mile period from Ethyl's fleet test program. For the cars with mileages greater than 75,000 miles, Ethyl assumed that the HiTEC 3000 additive effect stays the same as at the 75,000 mile <u>point</u> from Ethyl's fleet test program. This assumption is most likely conservative as the trend for CO and NOx continues to decrease with increasing mileage.

The resultant HiTEC 3000 additive effect for the U.S. automobile

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[5] See Appendix 1, Attachment 1-1.

fleet in 1999 is a decrease of 0.28 gm/mile and 0.18 gm/mile per automobile for CO and NOx, respectively (Attachment 7-4). Actual total reductions by pollutant are provided below.

A. NOx

The use of the HiTEC 3000 additive in unleaded gasoline would lead to a substantial reduction in NOx emissions. NOx emissions from automobiles would drop by up to 633 million pounds per year in 1999 (See Attachment 7-5). This reduction was calculated by multiplying the HiTEC 3000 additive effect for NOx (described above) times the average number of miles driven by each automobile per year (assumed to remain constant at the 1988 level of 11,300 miles per year). This number is then multiplied by the number of total automobiles in operation for 1999 (obtained from Attachment 7-2) and then divided by the appropriate constants to obtain pounds per year.

To estimate the overall effect of these NOx emission reductions, Ethyl relied on Chapter 7 of the Congress of the United States Office of Technology Assessment publication "Catching Our Breath -- Next Steps for Reducing Urban Ozone". In this publication, the contribution to NOx emissions from passenger cars is estimated to be 17 percent of the total in 1985. The total NOx emissions from all sources is estimated to be 44.4 billion pounds per year in 1999. The resultant reduction from the use of the HiTEC 3000 additive would therefore represent a decrease in NOx emissions of 8.4% in 1999. However, this calculated decrease may be understated. The results from Ethyl's fleet test program indicate that the HiTEC 3000 additive reduced NOx emissions by 20% averaged over the 75,000 miles accumulated by each automobile.

In addition, NOx emissions from refineries would fall by up to 11 million pounds per year.[6] Total NOx emission reductions from use of the HiTEC 3000 additive would therefore amount up to 644 million pounds per year in 1999.

B. CO

The use of the HiTEC 3000 additive will also reduce total CO emissions. CO emissions from automobiles would drop by as much as 985 million pounds per year in 1999 (See Attachment 7-6). The calculation follows the same logic as described above for NOx reductions. The 985 million pounds is estimated to represent a 7.7% reduction in automotive CO emissions based on data from Ethyl's 75,000 mile fleet test program.

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[6]See Appendix 6, Attachment 6-1, p. 1.

As with the emissions of NOx, the emission of CO from refineries would fall by up to 3 million pounds per year.[7] The combined reduction in CO emissions would therefore total up to 988 million pounds per year in 1999.

C. HC

The HC emission data from Ethyl's 48-car fleet test program indicate that the HiTEC 3000 additive exhibits a very small, but statistically detectable, increase in HC tailpipe emissions that ranges from 0.010 gm/mile to 0.018 gm/mile averaged across the 75,000 miles, depending upon the method of analysis.[8] Using the same calculation and logic as described for NOx above, the resultant increase in tailpipe HC emissions in 1999 range from 35 to 63 million pounds per year. Ethyl believes, however, that in commercial operation, this calculated increase in total HC emissions will not occur because of the lower aromatic content of gasoline made possible by use of the HiTEC 3000 additive.

Use of the HiTEC 3000 additive will allow refiners to reduce the amount of aromatics in gasoline by an estimated 1.2 to 2.0 percentage points by volume (See Appendix 6; Appendix 9). Because the HiTEC 3000 additive increases the octane quality of gasoline, the refiner can reformulate gasoline by removing high-octane components, such as heavy aromatics, otherwise required to meet the octane quality specification.

Information published by the petroleum and automotive industries describes a relationship between heavy aromatics and HC tailpipe emissions; namely, a fuel containing a large amount of heavy aromatic components will increase the amount of HC emissions emitted from the tailpipe.[9] A presentation by General Motors to the CRC Automotive and APRAC Committees on June 20, 1989 shows that removing the heavy aromatic components of a gasoline can reduce the HC tailpipe emissions by up to 38 percent, from 0.79 gm/mile to 0.49 gm/mile.[10] The GM data indicate that reducing the aromatic content of a fuel from 49% to 31% lowered the associated tailpipe HC emissions from 0.79 gm/mile to 0.58 gm/mile. Similarly, a reduction in aromaticity from 49% to 13% lowered the HC emissions from 0.79 gm/mile to 0.49 gm/mile.

Based on the GM data, a calculation can be made to estimate the

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[7]See Appendix 6, Attachment 6-1, p.1.

[8]See Appendix 2A.

[9]See Appendix 9.

[10]See Appendix 9, Attachment 9-1.

reduction in HC emissions that would occur for each percentage point reduction in aromatic content of gasoline. For example, the calculation for a reduction in aromatics from 49 to 31 percent of the fuel by volume is as follows:

$$(0.79 - 0.58) / (49 - 31) = 0.012 \text{ gm/mile.}$$

Similarly, reducing aromatics from 49% to 13% by volume results in a calculated reduction in HC emissions of 0.008 gm/ mile for each percentage point reduction in aromatic content.

Applying these calculated HC emission reductions and assuming that the use of the HiTEC 3000 additive reduces aromatics in gasoline by 1.2 to 2.0 percent, the estimated reduction in HC emissions in commercial operation with the HiTEC 3000 additive could range from <u>0.01 gm/mile</u> to as high as <u>0.024 gm/mile</u>. This reduction in HC emissions attributable to reductions in the aromaticity of fuel is sufficient to offset the small HC emission increase exhibited in Ethyl's test data. As noted, the small increase in HC emissions exhibited in Ethyl's test data was as little as 0.010 gm/mile and no more than 0.018 gm/mile. For this reason, use of the HiTEC 3000 additive should not increase total HC emissions.

D. <u>Sulfur Oxides and Particulates</u>

Refinery emissions of sulfur oxides could be reduced by up to 150,000 pounds per year if the HiTEC 3000 additive was available as an unleaded fuel additive.[11] Similarly, the emission of particulates could be reduced by up to 1.1 million pounds per year.[12] As with NOx and CO, the severity of the refining process can be reduced when the HiTEC 3000 additive is added to unleaded gasoline. This reduced severity in the refining process results in decreased emissions.

Additionally, the use of the HiTEC 3000 additive could result in lower particulate matter being emitted from the automobile tailpipe. Ethyl measured airborne particulate on three models from its test fleet at 75,000 miles. The results showed that, directionally, the use of the HiTEC 3000 additive decreased the amount of particulate emitted from the tailpipe. The average reduction in particulate for the automobiles using the HiTEC 3000 additive was <u>0.003 gm/mile</u>. Particulate emissions for the nine cars fueled with clear Howell EEE averaged 0.007 gm/mile while the nine cars using fuel containing the HiTEC 3000 additive

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[11] See Appendix 6, Attachment 6-1, p.1.

[12] See Appendix 6, Attachment 6-1, p.1.

averaged only 0.004 gm/mile.[13]

E. Carbon Dioxide

While carbon dioxide (CO_2) is a natural component of the atmosphere, some scientists theorize that increased levels of CO_2 contribute to the overall warming of the earth's atmosphere, which is known as the "greenhouse effect". By allowing the use of the HiTEC 3000 additive, emissions of CO_2 to the atmosphere from refineries could fall by up to 10 billion pounds per year.[14]

F. Aromatics

The Turner, Mason & Company report found in Appendix 6 reports that the average aromatic content of U.S. unleaded gasoline will decrease by 1.2 percentage points (from 31.2 percent to 30 percent of the volume of unleaded gasoline) if the HiTEC 3000 additive is allowed to be used.[15] This lower aromatic content will also reduce the amount of aromatics, including benzene, in automotive exhaust emissions.

As part of Ethyl's fleet test program, two Ford Crown Victorias from Ethyl's test fleet were sent to Southwest Research Laboratories in San Antonio for speciation testing. Approximately 6% mixed xylenes were added to one batch of a commercial gasoline to make the octane of the blend the same as the commercial gasoline containing 0.03125 gm Mn/gal. as HiTEC 3000. The detailed results of this program are described in Appendix 4.

Results of the speciation analysis of the commercial gasoline indicate that the fuel containing the HiTEC 3000 additive emitted about 0.03 gm/mile less aromatics.[16] Studies have shown that the aromatic content of gasoline can be reduced by 1.2 to 2.0 percentage points by using the HiTEC 3000 additive. Assuming a 2 percentage point reduction in aromatic content of gasoline with the use of the HiTEC 3000 additive and assuming that a linear relationship exists between aromatic content of gasoline and aromatics emitted from the tailpipe, the actual effect of the HiTEC 3000 additive in normal use would be the ratio of 2 percent to the 6 percent increased aromatics from the speciation study

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[13] See Appendix 3, Attachment 3-23.

[14] See Appendix 6, Attachment 6-1, p.1.

[15] See Appendix 6, Attachment 6-1, p.2.

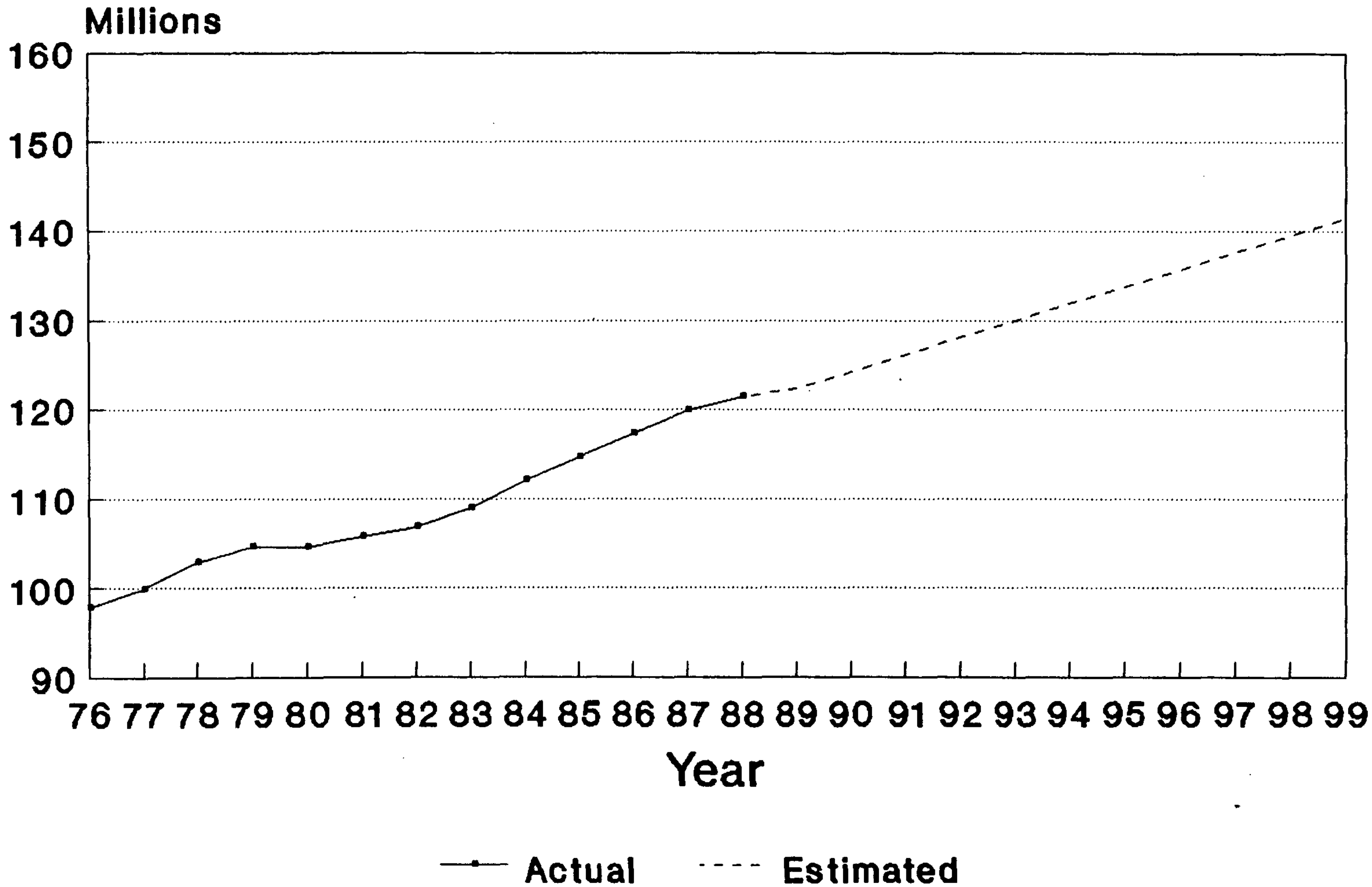
[16] See Appendix 4, Attachment 4-8.

described above. Ethyl estimates that the overall reduction in aromatics emitted from the automobile tailpipe to be one-third of 0.03 gm/ mile or about 0.01 gm/mile. Using the same calculation described in Section A above, the overall effect would be a reduction of approximately 35.2 million pounds of aromatics emitted in 1999 if HiTEC 3000 were used in gasoline.

Included in the 35.2 million pound reduction of aromatics emitted from the tailpipe in 1999 if the HiTEC 3000 additve was allowed to be used in unleaded gasoline, is an approximate 3.5 million pound reduction in benzene, a noxious aromatic compound. The speciation analysis of the commercial gasoline, described above, shows a decrease of 0.004 gm/mile for benzene. Using the same logic as explained in the previous paragraph, Ethyl estimates that the overall reduction in benzene emissions from the automobile tailpipe by using the HiTEC 3000 additive is one-third of 0.004 gm/mile or approximately 0.001 gm/mile. The resultant calculation, as described in Section A, is a total annual reduction of 3.5 million pounds of benzene emitted from the tailpipe in 1999.

The use of HiTEC 3000 will also allow the reduction of formaldehyde, another noxious compound. The speciation study described in Appendix 4 resulted in a decrease of 0.002 gm/mile formaldehyde when vehicles are fueled with unleaded gasoline containing the HiTEC 3000 additive. The estimated reduction of formaldehyde emitted from the tailpipe through the use of the HiTEC 3000 additive is one-third of 0.002 or approximately 0.001 gm/mile when rounded up to the nearest one thousandth. This reduction, although small, represents a decrease of approximately 3.5 million pounds of toxics emitted from the tailpipe in 1999.

TOTAL CARS IN OPERATION -- U.S.



Attachment 7-1

Attachment 7-2

TOTAL CARS IN OPERATION -- U.S.

(Millions of Automobiles)

Year	Pre-'75	'75-'80	Post-'80	Total
1981	46390	54309	5140	105839
82	40811	53377	12679	106867
83	35918	52297	20746	108961
84	31079	50805	30135	112019
85	26149	48373	40140	114662
86	21481	45205	50582	117268
87	17803	41553	60493	119849
88	14560	37228	69731	121519
89	11508	32271	78566	122345
90	8487	28216	87550	124253
91	5245	25522	95393	126160
92	2810	21800	103457	128067
93	1522	18234	110219	129975
94	700	13952	117230	131882
95	0	10001	123789	133790
96	0	7000	128697	135697
97	0	4001	133604	137605
98	0	2000	137512	139512
99	0	0	141420	141420

Note -- Figures are estimated beginning in 1989.

Attachment 7-3

U.S. CAR STATISTICS

Car Age Years	Population Percent	Avg. Annual Miles Driven
0-6	51.4	13,000
7-8	12.1	11,730
9-10	13.1	10,112
11-15	15.7	8,755
16 or over	7.7	6,859

Data obtained from MVMA "Facts and Figures '89", pp. 26,28,45.

Attachment 7-4

1999 CASE

Assumptions

1. HiTEC 3000 introduced January 1991.
2. All vehicles are 1981 models or newer.
3. From Attachment 7-3,

Car Age Years	Population Percent	Avg. Annual Miles Driven	% of Miles Driven
0-6	51.4	13,000	59
Over 6	48.6	9,540	41

4. 59% of miles driven are cars that are at some stage between 0 and 75,000 miles in equal increments.
5. 41% of miles driven are cars that are past 75,000 miles.
6. For cars past 75,000 miles, assume HiTEC 3000 effect stays the same as at 75,000 miles.

Calculation of Weighted HiTEC 3000 Effects

Car Age	HiTEC 3000 Effect Used	% Miles Driven	HiTEC 3000 Effect (gm/mile) CO	NOx
0-6	0-75,000 Mile Avg.	59	-0.22	-0.11
Over 6	75,000 Miles	41	-0.36	-0.27
	Weighted Effect		-0.28	-0.18

Attachment 7-5

HiTEC 3000 EFFECT -- TOTAL NOx EMISSIONS REDUCTION

1. Mobile Emissions

HiTEC 3000 Effect -- gm/mile
1999

-0.18

NOx Reduction(1999) = 0.18 gm/mile x 11,300 miles/auto-year
x 141.4 million autos 454 gm/lb.

= 633,000,000 lbs/year

2. Stationary Emissions

Reductions @ U.S. Refineries -- 11,000,000 lbs/year

TOTAL NOx EMISSION REDUCTIONS

1999 -- 644,000,000 lbs/year

Attachment 7-6

HiTEC 3000 EFFECT -- TOTAL CO EMISSIONS REDUCTION

1. Mobile Emissions

HiTEC 3000 Effect -- gm/mile
1999

-0.28

CO Reduction(1999) = 0.28 gm/mile x 11,300 miles/auto-year
x 141.4 million autos   454 gm/lb.

= 985,000,000 lbs/year

2. Stationary Emissions

Reductions @ U.S. Refineries -- 3,000,000 lbs/year

TOTAL CO EMISSION REDUCTIONS

1999 -- 988,000,000 lbs/year

Appendix 8

APPENDIX 8

Health and Environmental Implications of Use of HiTEC-3000 as a Fuel Additive

I. INTRODUCTION

During the combustion of gasoline containing the HiTEC-3000® Performance Additive ("the Additive"), greater than 99.9% of the manganese in the additive is converted into inorganic oxides of manganese, of which the principal form is the tetraoxide, Mn_3O_4. EPA and its science advisers have specifically addressed the public health implications of manganese emissions under the Clean Air Act ("Act"). They have found that emissions and ambient concentrations of manganese pose no public health concern, even in the vicinity of large point source emitters of this substance. Similarly, any additional manganese emissions resulting from the use of the Additive would present no public health concern.

II. MANGANESE

Man requires many minerals to sustain life. Manganese (Mn) is one of these essential trace elements. It is present naturally throughout our environment. As a result, it is present in trace quantities in the cells of all living organisms. Manganese appears to be involved in several essential biological processes, e.g., in lipid biosynthesis and oxidative phosphorylation and as a coenzyme for several enzymes, including hexokinase superoxide dismutase and xanthine oxidase. Without the presence of manganese in the body, several reactions essential for life cannot occur.

A. Manganese in the Environment

Manganese is an abundant and ubiquitous element. It is the twelfth most abundant element in the earth's crust, and one of the most abundant trace elements, ranking fourth after aluminum, iron, and titanium. Manganese is found in soil, water, air, food and consequently all life forms, in a wide range of concentrations.

1. Soil

Various data from the literature report manganese levels in soils from less than 1 ppm to 7,000 ppm. The average concentration of manganese in the earth's crust is about 1,000 ppm.

In agricultural environments, soil treatment can contribute significant quantities of manganese to that naturally present in soil. Typical manganese concentrations in soil supplements are, for example, limestone--850 ppm, sewage sludge--240 ppm, and rock phosphate--85 ppm.

2. Water

Since manganese occurs naturally in soil, it is also present in water. Samples of treated drinking water supplies from 100 of the largest U.S. cities had a median manganese concentration of 5 ug/L. The U.S. standard for manganese concentrations in drinking water is no greater than 50 ug/L. This standard is not based on any public health concern. Rather, it is a secondary standard based on aesthetic qualities, such as staining of plumbing fixtures.

3. Air

Background concentrations of manganese at rural sites unaffected by major point sources ranged from 0.005 to 0.012 ug/m^3 between 1972-82 on an annual basis.[1/] Manganese concentrations at these rural sites are due principally to naturally occurring sources of manganese, such as wind-blown dust.

Emissions from large point sources of manganese, e.g., manufacturing of ferroalloys, iron and steel, and fossil fuel combustion, add to these naturally occurring sources of airborne manganese concentrations. EPA has found that three source categories -- fossil fuel combustion, steel production, and ferroalloy production -- contribute approximately 3600 metric tons of the estimated 4100 metric tons of manganese emitted per year from all anthropogenic sources. Based on very conservative atmospheric modeling predictions, EPA estimated that the largest of these point sources could cause ambient manganese concentrations of up to 250 ug/m^3 for 15 minutes, and 125 ug/m^3 for 8 hours.[2/]

The U.S. National Air Surveillance Network reports data on the average ambient levels of manganese across the U.S. These

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1/ Final Health Assessment Document for Manganese, Docket No. II-A-3 ("HAD") at 3-68.

2/ 50 Fed. Reg. 32,628 (col. 2) (1985).

data show that ambient concentrations of manganese in the urban ambient air have decreased from an annual average of over 0.1 ug/m^3 in the 1950s to about 0.03 to 0.04 ug/m^3 in the 1970s and 1980s.[3/] This decrease has resulted largely from the use of particulate matter controls installed pursuant to the Clean Air Act.

4. Food

Given that manganese is present throughout our natural environment, manganese is found naturally in the food we eat each day. Indeed, food serves as the largest source of manganese for man.

Throughout the world, dietary intakes of manganese range from 2,000-9,000 ug daily, depending on the composition of the diet. Approximately 3-4% of dietary manganese is absorbed from the intestinal tract. While there is no official recommended dietary allowance for manganese, an intake of 2,000-5,000 ug/day is thought to be adequate for children and adults. One multivitamin tablet typically can contain 1,000-10,000 ug manganese.[4/]

[3/] See HAD, at 3-60 to 3-69. Airborne manganese concentrations have also been reported for the U.K. by the Warren Springs Laboratory. Levels reported are in the same range as U.S. values. On an annual basis, rural concentrations were about 0.012 ug/m^3 and urban area concentrations were in the 0.014 to 0.140 ug/m^3 range. See G. McInnes, Multi-Element and Sulphate in Particulate Surveys: Summary and Analysis of Five Years Results (1976-1981), Warren Springs Laboratory Report LR 435(AP), 1982.

[4/] See, e.g., a label of any multi-vitamin in mineral supplement, such as centrum.

Table 1 shows levels of manganese found in various food groups. Whole grains, cereals, and nuts contain large concentrations. Higher concentrations are found in tea leaves, one cup of tea containing up to 1200 ug of manganese. This probably accounts for the higher dietary levels reported for manganese in food in the U.K.

TABLE 1

TYPICAL LEVELS OF MANGANESE IN FOOD

Food	Manganese (ug/g wet weight (ppm))
Meat and Eggs	0-2.88
Grains and Cereals	1.17-30.76
Vegetables and Fruits	0.14-12.74
Fish	0.020-0.12
Milk, Whole	0.12
Tea Leaves	275.58
Cup of Tea	6.9

B. Impact of Use of the Additive On Manganese Emissions and Ambient Concentrations

Ethyl is proposing to use the Additive in unleaded gasoline in very small concentrations (0.03125 grams manganese per gallon, or approximately 8 mg/liter) as a fuel additive. Use of this additive will result in infinitesimal additional emissions of manganese. Testing of vehicles in the Ethyl test fleet (see

Appendix 3 for a detailed discussion) showed average tailpipe emissions of airborne manganese to be only 0.4 percent of the amount of manganese used in the fuel. (Previous data citing 15 to 30 percent were for non-catalytst cars and much higher manganese in fuel concentrations.[5/]) Thus, a current model automobile fueled on gasoline with the Additive (0.03125 grams of Mn/gallon) would release about 0.06 grams (0.00006 kilograms) of manganese on an annual basis, assuming (1) the car was driven 12,000 miles in a year, (2) it consumed fuel at the rate of 25 miles per gallon, and (3) 0.4 percent of the manganese was emitted. Under these assumptions, approximately 0.5 grams of manganese would be emitted over the course of 100,000 miles of vehicle operation.

Moreover, any increased ambient concentrations of manganese due to use of the Additive will be very small. For example, in a typical large urban area like Philadelphia, one could expect, conservatively, maximum increased ambient concentrations of manganese of only about 0.0009 ug/m^3.[6/] This increased concentration is well below those caused by point sources, and

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[5/] HAD at 3-38.

[6/] Systems Applications, Inc. ("SAI"), a statistical consultant retained by Ethyl to analyze Ethyl's 48-car test fleet data and to conduct an analysis of the impact of the Additive on the formation of ozone using the Urban Airshed Model, calculated the maximum hourly manganese concentration attributable to use of the Additive. SAI estimated the maximum hourly increase by taking the ratio of manganese tailpipe emissions to CO tailpipe emissions and applying this ratio to the maximum calculated CO concentration. See Appendix 5, at 65.

means that use of the Additive would produce maximum ambient manganese concentrations that are over <u>one million times smaller</u> than the OSHA standard for manganese fume of 1000 ug/m^3 (the standard for dust is 5000 ug/m^3).

That the Additive would not measurably contribute to ambient concentrations of manganese is borne out by monitoring data from Canada and the U.S. For example, the Additive has been used in virtually all unleaded gasoline in Canada for well over a decade at concentrations up to 0.0681 grams Mn/U.S. Gallon (18 mg/liter) (over two times higher than the concentration proposed here by Ethyl). Ambient concentrations of manganese are routinely measured in Quebec, Ontario and British Columbia in the measurement of airborne particulates. Ontario has an especially extensive network of sampling sites with results from 185-200 sites reported each year from 1982 to 1987.[7/] The data from these monitoring regions are summarized in Attachment 8-1.

These data show that manganese levels in large cities (i.e., population greater than 100,000) without major point sources are only about 0.020 ug/m^3 higher than levels found in rural areas (i.e., towns with population less than 30,000). Moreover, as expected, these monitoring data find that concentrations of manganese in air near point sources are higher than in areas without point sources. Thus, ambient manganese concentrations are a function of normal background concentrations and large

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[7/] These sites include at least two sites located in downtown Toronto.

point sources, while use of the Additive in fuel during this period had no discernable effect on ambient manganese concentrations.

The experience with the Additive in the U.S. during the 1970s is also instructive with respect to its effect, if any, on ambient manganese concentrations. It was first used in unleaded gasoline in 1974. Prior to that time, the Additive had been used in leaded fuels. Between 1975 and 1977, annual sales of the Additive increased from about 1 million pounds to over 7 million pounds. Despite its widespread use during these years, ambient monitoring data from the National Air Surveillance Network show that mean annual manganese concentrations for urban sites declined from 1970 (0.07 ug/m^3) to 1976 (0.04 ug/m^3). Mean ambient concentrations from 1976 to the present have remained relatively stable in the 0.03 to 0.04 ug/m^3 range.[8/] These data confirm that the Additive has no detectable impact on ambient manganese concentrations, as compared to natural background and large points sources.

C. Health Implications of Manganese Emissions

1. Manganese Ingestion

Given that manganese is present in our everyday environment and is an essential nutrient, manganese forms a part of everyone's diet. Dietary intakes of manganese range from 2,000 to 9,000 ug per day. The total average amount of manganese

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[8/] *See* HAD, at 3-67.

actually absorbed into the body from food and water is estimated to be approximately 120 ug per day. Of this 120 ug, airborne manganese is an insignificant amount, with normal dietary uptake levels more than 100 times greater than absorbed inhaled manganese. (See Table 2).

TABLE 2

ESTIMATED DAILY ADULT EXPOSURE TO MANGANESE

Daily Intake	
Food and Water	2,000-9,000 ug (use 3,000 ug mean)
Absorption Rate	3-4%
Avg. Amount Absorbed	120 ug
Air (0.04 ug/m^3 X 20 m^3 inhaled)	0.8 ug
Absorption Rate	25-50%
Avg. Amount Absorbed	0.4 ug
Total Daily Uptake (Food and Water Plus Air)	120.4 ug

From these approximations, it is clear that exposure to airborne manganese represents an insignificant contribution to man's total daily manganese uptake.

It is also important that among the trace elements, manganese is one of the least toxic to man. Metabolism is controlled efficiently by homeostatic mechanisms, so that tissue concentrations are maintained at stable levels despite large natural variations in manganese intake.[9/]

Blood levels of manganese absorbed from all sources reported in the literature are on the order of 0.86 to 1.45 ug manganese/dL whole blood. Moreover, tissue concentrations are rather constant throughout man's lifetime with no tendency to accumulate or decrease with age.[10/] As a result, the insignificant contribution of use of the Additive to ambient manganese concentrations will contribute essentially nothing to these typical levels of manganese in the body.

2. **Airborne Manganese**

As part of its ongoing review of anthropogenic emissions of metals and other substances, the U.S. EPA in 1984 issued a Health Assessment Document for Manganese ("HAD"), which represents a comprehensive review of current knowledge of the health effects of exposure to environmental manganese. The document covered sources of manganese, environmental and exposure levels, and acute and chronic health effects.

The HAD report stated that no data have shown manganese to have carcinogenic effects in humans.[11/] Likewise, studies have not shown any significant noncarcinogenic health risks from exposure to manganese in the ambient air.

[9/] Schroeder et al, Essential Trace Elements in Man: Manganese A Study in Homeostasis, J. Chron. Dis., 19 (1966) 545-571.

[10/] Id.

[11/] HAD at 1-12, 2-11.

EPA noted five human studies on the respiratory effects of manganese in particulate matter, three of which were occupational, and therefore not directly applicable to an evaluation of health effects associated with the extremely low manganese concentrations in the ambient air. These studies reported only noncarcinogenic health effects (respiratory and neurotoxic), where workers were exposed to work place concentrations of manganese in excess of 5,000 ug/m^3 on an 8-hour basis, a level over 100,000 times greater than the 0.02 to 0.04 ug/m^3 concentrations characteristic of ambient air in rural and urban environments.

Of the remaining two studies examined in the HAD, one, a study of residents of a town containing a ferro-manganese plant, was inconclusive according to EPA. The second, a 1973 study of Japanese school children exposed to emissions from a ferro-manganese plant, indicated an increased prevalence of minor respiratory effects associated with high (200 kg/Km^2 per month) levels of settled dust. Thus, as EPA has correctly noted, while exposure to particulate matter in general may cause "common respiratory ailments" in the general population, such ailments are in no way attributable to the manganese fraction of the particulate matter.[12/] Moreover, such minor effects are protected in the U.S. by the particulate matter (now PM-10) ambient standard.

12/ 50 Fed. Reg. 32,627 (col. 3) (1985).

EPA, therefore, concluded that "ambient air concentrations of manganese [in the U.S.] do not pose a significant risk to public health."[13/] Indeed, studies prepared for EPA show that even the most minor observable respiratory symptoms associated with manganese inhalation would occur only at levels much greater than "recently measured" concentrations of manganese in the ambient air.[14/] As EPA's studies have shown, concentrations of manganese in the ambient air, "even in the vicinity of major manganese emitting facilities" such as ferroalloy producers (the largest single emitters), are adequately limited by EPA's present NAAQS for particulate matter to levels much lower than those that would produce even minor health effects.[15/] The insignificant contribution to ambient manganese concentrations that would result from use of the Additive would, therefore, have absolutely no bearing on public health.

Several specific assessments of the health aspects of exposure to manganese from combustion of the Additive have been completed and confirm EPA conclusions. Peter Abbott, a medical investigator for the Australian government, reported in 1987 the results of a toxicological assessment of the use of the Additive and concluded there is no evidence that use of this gasoline

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13/ 50 Fed. Reg. 32,627 (col. 2) (1985).

14/ GCA Corp., (1984) Regulatory Options Analysis for Manganese (March 1984), Docket No. II-A-1 at 1-I ("GCA Analysis").

15/ 50 Fed. Reg. 32,628 (col. 2) (1985).

additive would constitute a health risk to the general population. He concluded that:

> "The small increase in airborne manganese from the use of MMT in petrol is 3-4 orders of magnitude [i.e., 1,000 to 10,000 times] lower than the level required to produce toxic symptoms of manganese exposure, even in areas of high traffic density, and no health risk from the use of MMT is likely."[16/]

W.C. Cooper, a well-known epidemiologist, completed a comprehensive review of the health implications of the Additive and concluded that the minute increments of manganese resulting from its use should not have any impact on the public health. Cooper stated that:

> "There is thus a wide margin of safety between the intakes of manganese essential to health and the high concentrations that have been associated with toxic effects. The small amounts of manganese added to the environment by the combustion of MMT used as a fuel additive would be comparable to the normal background and should not create health problems."[17/]

Thus, use of the Additive will not result in ambient manganese concentrations that present any public health concern.

III. EXPOSURE TO THE ADDITIVE

The Additive has been studied extensively in animal exposure

16/ Abbott, Peter J., "Methlcyclopentadienyl Manganese Tricarbonyl (MMT) in Petrol: The Toxicological Issues," The Science of the Total Environment, 67:247-255, 1987.

17/ Cooper, W.C., "The Health Implications of Increased Manganese in the Environment Resulting from the Combustion of Fuel Additives: A review of the Literature," J. Toxicology and Environmental Health 14:23, 1984.